

— EPE —
NEW NAME
NEW DESIGN!



Practical Electronics

The UK's premier electronics and computing maker magazine

Audio Out

Amazing analogue
noise sound effects

PIC n' Mix

Audio Spectrum
Analyser

Circuit Surgery

Impedance
measurement

Arduino/XOD

Programmable
flexible timer



ARDUINO

Visual programming
for Arduino with XOD

Superb
bridge-mode
amplifier



Using FPGAs
with iCEstick



Remote control for
ultra-low-distortion
Preamplifier



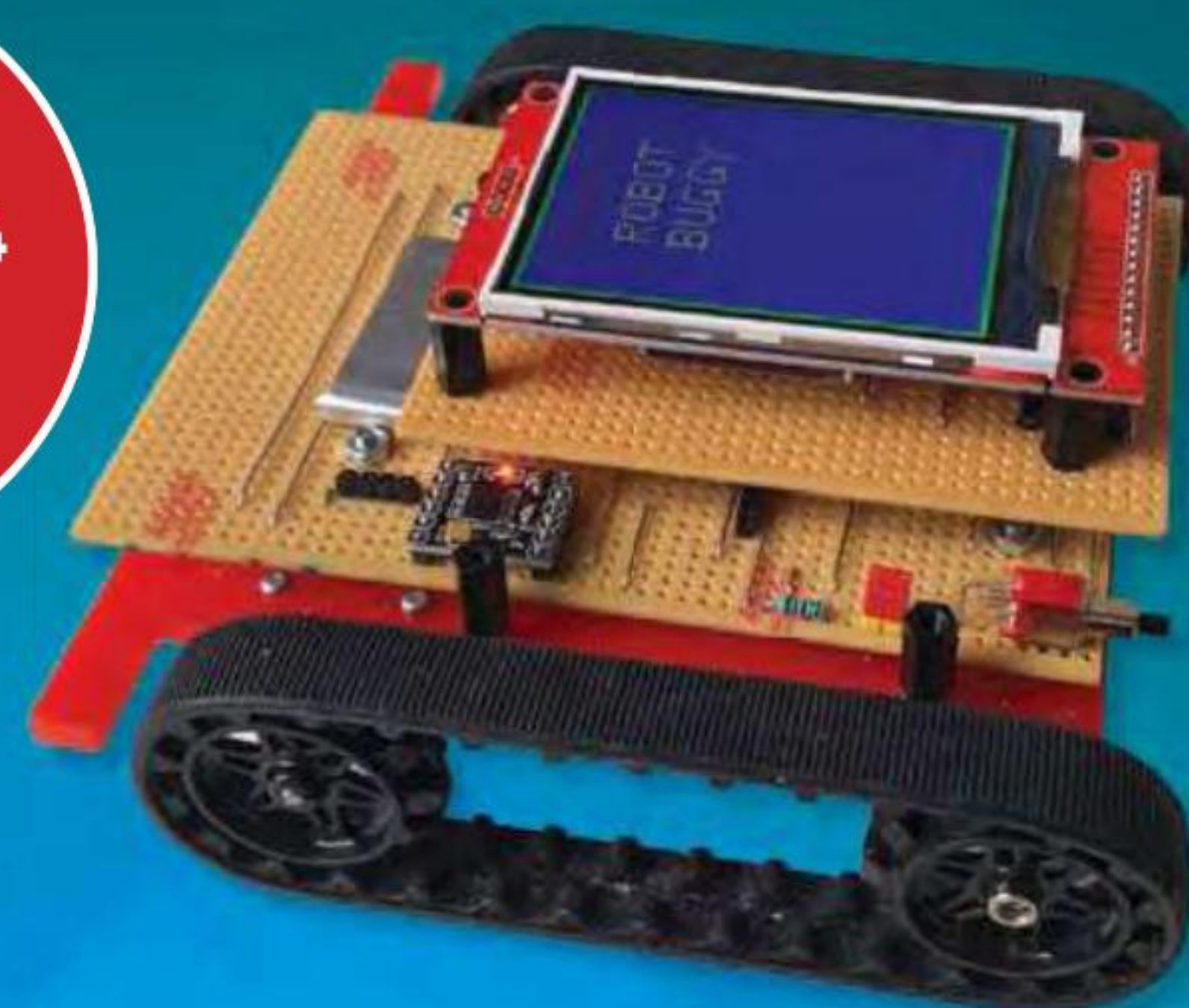
PLUS!

Net Work – Live on-demand digital terrestrial TV

Max's Cool Beans – Even more flashing LEDs!

Techno Talk – Is IoT risky?

WIN!
Microchip
MPLAB ICD 4
In-Circuit
Debugger
WIN!



Build a Micromite
programmable
robot buggy



433MHz
Repeater

May 2020 £4.99



With Over 250 Million Units in Stock, We've Got You Covered

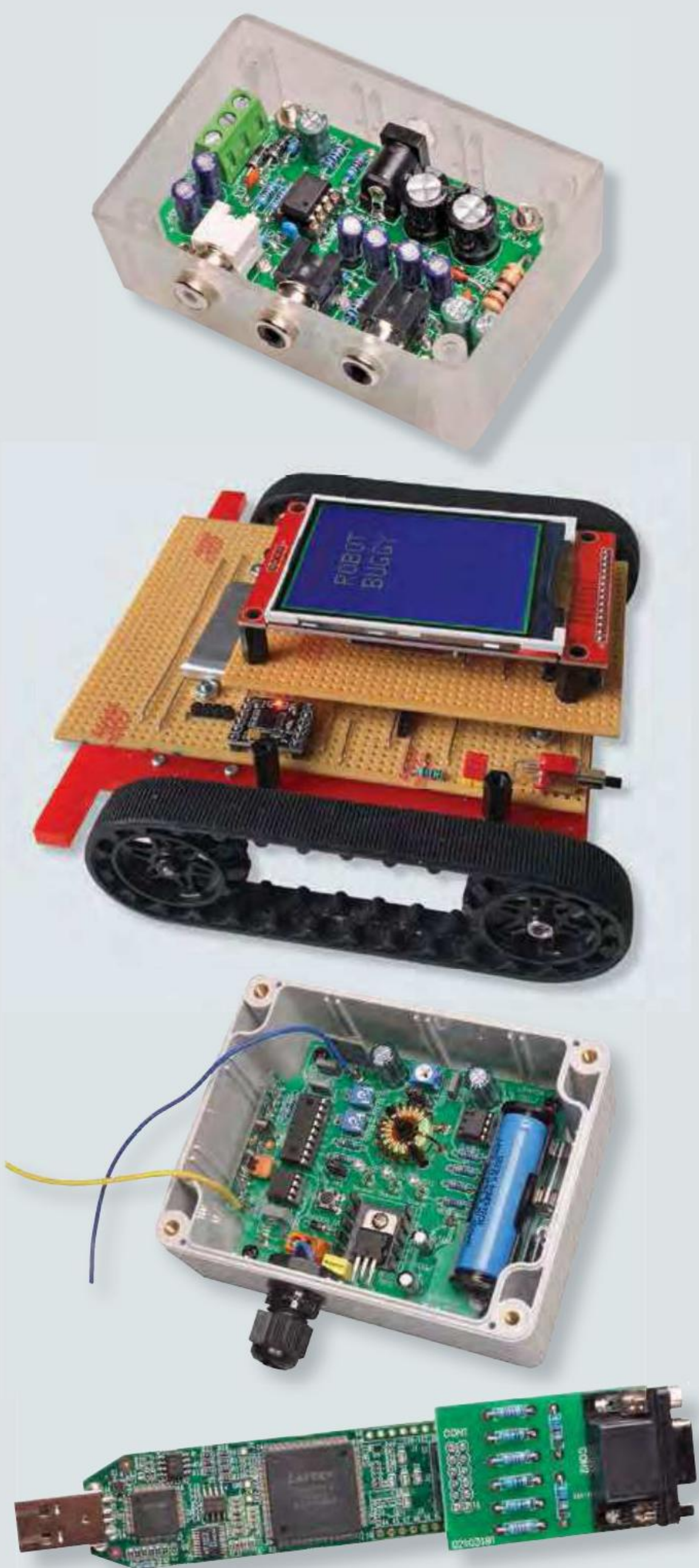
Delivering You the World's Largest Inventory of Microchip Products



www.microchip.com/buy



The Microchip name and logo and the Microchip logo are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.
All other trademarks are the property of their registered owners.
© 2020 Microchip Technology Inc. All rights reserved. DS00002552A. MEC2310A-ENG-01-20



Made in the UK.

Written in Britain, Australia,
the US and Ireland.

Read everywhere.

© Electron Publishing Limited 2020

Copyright in all drawings, photographs, articles, technical designs, software and intellectual property published in *Practical Electronics* is fully protected, and reproduction or imitation in whole or in part are expressly forbidden.

The June 2020 issue of *Practical Electronics* will be published on Thursday, 7 May 2020 – see page 80.

Projects and Circuits

- 433MHz Wireless Data Range Extender** by John Clarke 16
Is your remote control 100% reliable? Is the range a bit less than you'd like? Here's the answer: a small, solar-powered 433MHz repeater.
- Bridge-mode Audio Amplifier Adaptor** by Nicholas Vinen 24
Use this easy-to-build unit with a standard stereo amplifier to unlock immense power from an audio amplifier and speaker.
- iCEstick – Part 2** by Tim Blythman 30
Want to give a project the retro-computer look? Generate a VGA signal akin to something from an early PC using a low-cost iCEstick FPGA development board.
- Ultra-low-distortion Preamplifier with Tone Controls – Part 2** by John Clarke 38
Build the input selection boards and power supply for our state-of-the-art stereo preamplifier with almost unmeasurable noise and distortion – 0.0003% THD+N!

Series, Features and Columns

- Publisher's statement** by Matt Pulzer 6
A message to all readers of *Practical Electronics*
- The Fox Report** by Barry Fox 8
Welcome to the key-free zone
- Techno Talk** by Mark Nelson 10
Joy or dread: do we get a choice?
- Net Work** by Alan Winstanley 12
We look at the jargon-loaded mess that greets TV users when trying to decide what to watch and how to record it.
- Circuit Surgery** by Ian Bell 44
Impedance measurement and Howland current sources
- PIC n' Mix** by Mike Hibbett 48
Audio Spectrum Analyser – bandwidth expansion
- Make it with Micromite** by Phil Boyce 53
Part 16: Introduction to the Micromite Robot Buggy
- Audio Out** by Jake Rothman 58
Noise about noise – a new slant on analogue noise with tilt control – Part 2
- Visual programming with XOD** by Julian Edgar 62
Instant pushbutton timer
- Max's Cool Beans** by Max The Magnificent 66
Flashing LEDs and drooling engineers – Part 3, plus cunning coding tips and tricks

Regulars and Services

- PE Teach-In 9** 3
- Subscribe to Practical Electronics and save money** 4
- Reader services – Editorial and Advertising Departments** 7
- Editorial** 7
What a difference a month makes... Please support our advertisers!... Take your PIC
- Exclusive Microchip reader offer** 11
Win a Microchip MPLAB ICD 4 In-Circuit Debugger
- Wireless for the Warrior** 15
- Practical Electronics back issues CD-ROM – great 15-year deal!** 37
- PE Teach-In 8** 65
- Practical Electronics – get your back issues here!** 65
- Direct Book Service** 73
Build your library of carefully chosen technical books
- Practical Electronics PCB Service** 76
PCBs for Practical Electronics projects
- Teach-In bundle – what a bargain!** 78
- Classified ads and Advertiser index** 79
- Next month! – highlights of our next issue of Practical Electronics** 80



Quasar Electronics Limited
PO Box 6935, Bishops Cleeve
CM23 4WP, United Kingdom

Tel: 01279 467799
E-mail: sales@quasarelectronics.co.uk
Web: quasarelectronics.co.uk

All prices INCLUDE 20.0% VAT. Free UK delivery on orders over £48
Postage & Packing Options (Up to 0.5Kg gross weight): UK Standard 3-7
Day Delivery - £4.95; UK Mainland Next Day Delivery - £9.95; Europe
(EU) - £12.95; Rest of World - £14.95 (up to 0.5Kg).
!! Order online for reduced price postage and fast despatch !!
Payment: We accept all major credit/debit cards. Make cheques/PO's
payable to Quasar Electronics Limited.
Please visit our online shop now for full details of over 1000 electronic
kits, projects, modules and publications. Discounts for bulk quantities.



QuasarElectronics.co.uk

Solutions for Home, Education & Industry Since 1993



Official Main Dealer stocking the full range of Kits, Modules, Robots, Instruments, tools and much, much more...

PIC & ATMEL Programmable

We have a wide range of PIC, ATMEL Arduino and Raspberry Pi projects.

PIC Programmer & Experimenter Board

Great learning tool. Includes programming examples and a reprogrammable 16F627 Flash Microcontroller. Test buttons & LED indicators. Software to compile & program your source code is included. Supply: 12-15Vdc. Pre-assembled and ready to use.
Order Code: VM111 - ~~£38.88~~ **£35.94**



USB PIC Programmer and Tutor Board

The only tutorial project board you need to take your first steps into Microchip PIC programming using a PIC16F882 (included). Later you can use it for more advanced programming. Programs all the devices a Microchip PICKIT2™ can! Use the free Microchip tools for PICKIT2™ & MPLAB® IDE environment.
Order Code: EDU10 - **£46.74**



USB /Serial Port PIC Programmer

Fast programming. Wide range of PICs supported (see website for details). Free Windows software & ICSP header cable. USB or Serial connection. ZIF Socket, leads, PSU not included.
Kit Order Code: 3149EKT - ~~£49.96~~ **£29.95**
Assembled Order Code: AS3149E - **£44.95**
Assembled with ZIF socket Order Code: AS3149EZIF - ~~£74.96~~ **£49.95**



PICKIT™2 USB PIC Programmer Module

Versatile, low cost, PICKIT™2 Development Programmer. Programs all the devices a Microchip PICKIT2 programmer can. Onboard sockets & ICSP header. USB powered.
Assembled Order Code: VM203 - **£35.94**



Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code 660.446UK £10.68

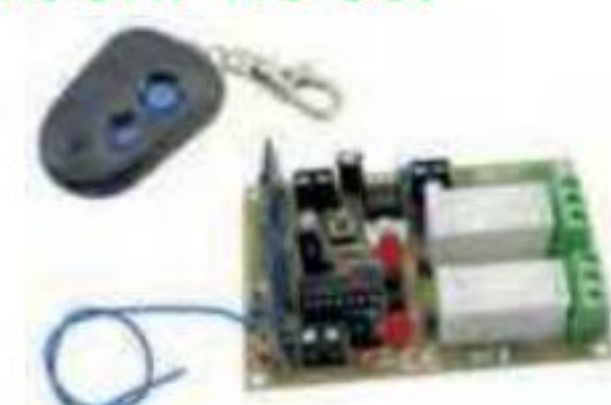
USB Experiment Interface Board

Updated Version! 5 digital inputs, 8 digital outputs plus two analogue inputs and two analogue outputs. 8 bit resolution. DLL.
Kit Order Code: K8055N - ~~£39.95~~ **£22.20**
Assembled Order Code: VM110N - **£35.94**



2-Channel High Current UHF RC Set

State-of-the-art high security. Momentary or latching relay outputs rated to switch up to 240Vac @ 12 Amps. Range up to 40m. 15 Tx's can be learnt by one Rx. Kit includes one Tx (more available separately). 9-15Vdc.
Kit Order Code: 8157KT - **£44.95**
Assembled Order Code: AS8157 - **£49.96**



Computer Temperature Data Logger

Serial port 4-ch temperature logger. °C/°F. Continuously log up to 4 sensors located 200m+ from board. Choice of free software applications downloads for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS18S20 sensor.
Kit Order Code: 3145KT - ~~£19.95~~ **£16.97**
Assembled Order Code: AS3145 - **£19.96**
Additional DS18S20 Sensors - **£4.96 each**



8-Channel Ethernet Relay Card Module

Connect to your router with standard network cable. Operate the 8 relays or check the status of input from anywhere in world. Use almost any internet browser, even mobile devices. Email status reports, programmable timers... Test software & DLL online.
Assembled Order Code: VM201 - **£130.80**



Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£15.26**
Assembled Order Code: AS3179 - **£22.26**



Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/5A) in both the forward and reverse directions. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections. PCB: 90x42mm.
Kit Order Code: 3166KT - **£19.99**
Assembled Order Code: AS3166 - **£29.99**



8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our free Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc, 500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**



8-Channel RF Remote Control Set

Control 8 onboard relays with included RF remote control unit. Toggle or momentary mode for each output. Up to 50m range. Board Supply: 12Vac, 500mA
Assembled Order Code: VM118 - **£71.94**



Temperature Monitor & Relay Controller

Computer serial port temperature monitor & relay controller. Accepts up to four Dallas DS18S20 / DS18B20 digital thermometer sensors (1 included). Four relay outputs are independent of the sensors giving flexibility to setup the linkage any way you choose. Commands for reading temperature / controlling relays are simple text strings sent using a simple terminal or coms program (e.g. HyperTerminal) or our free Windows application. Supply: 12Vdc.
Kit Order Code: 3190KT - ~~£79.96~~ **£47.95**
Assembled Order Code: AS3190 - **£59.95**



3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone or 2-wire serial interface for microcontroller or PC communication with simple command set. Suits common anode RGB LED strips, LEDs, incandescent bulbs. 12A total max. Supply: 12Vdc. 69x56x18mm
Kit Order Code: 8191KT - **£24.95**
Assembled Order Code: AS8191 - **£27.95**



**Card Sales
& Enquiries**

**01279
467799**

GET THE
LATEST COPY
OF OUR
TEACH-IN SERIES
AVAILABLE
NOW!

Order direct from Electron Publishing

PRICE £8.99
(includes P&P to UK if ordered direct from us)

Teach-In 9 – Get Testing!

This series of articles provides a broad-based introduction to choosing and using a wide range of test gear, how to get the best out of each item and the pitfalls to avoid. It provides hints and tips on using, and – just as importantly – interpreting the results that you get. The series deals with familiar test gear as well as equipment designed for more specialised applications.

The articles have been designed to have the broadest possible appeal and are applicable to all branches of electronics. The series crosses the boundaries of analogue and digital electronics with applications that span the full range of electronics – from a single-stage transistor amplifier to the most sophisticated microcontroller system. There really is something for everyone!

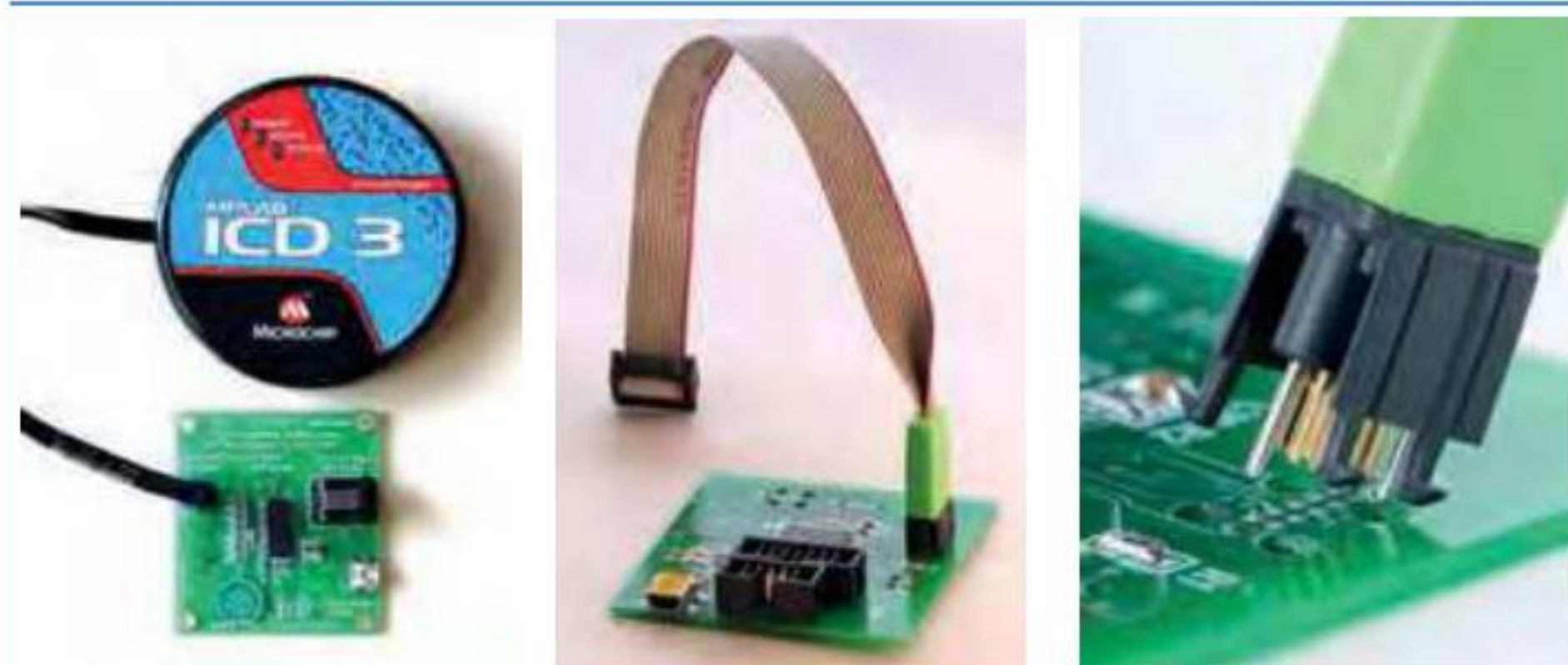
Each part includes a simple but useful practical test gear project that will build into a handy gadget that will either extend the features, ranges and usability of an existing item of test equipment or that will serve as a stand-alone instrument. We've kept the cost of these projects as low as possible, and most of them can be built for less than £10 (including components, enclosure and circuit board).

FREE COVER-MOUNTED CD-ROM

On the free cover-mounted CD-ROM you will find the software for the *PIC n' Mix* series of articles. Plus the full *Teach-In 2* book – *Using PIC Microcontrollers – A practical introduction* – in PDF format. Also included are Microchip's *MPLAB ICD 4 In-Circuit Debugger User's Guide*; *MPLAB PICkit 4 In-Circuit Debugger Quick Start Guide*; and *MPLAB PICkit4 Debugger User's Guide*.

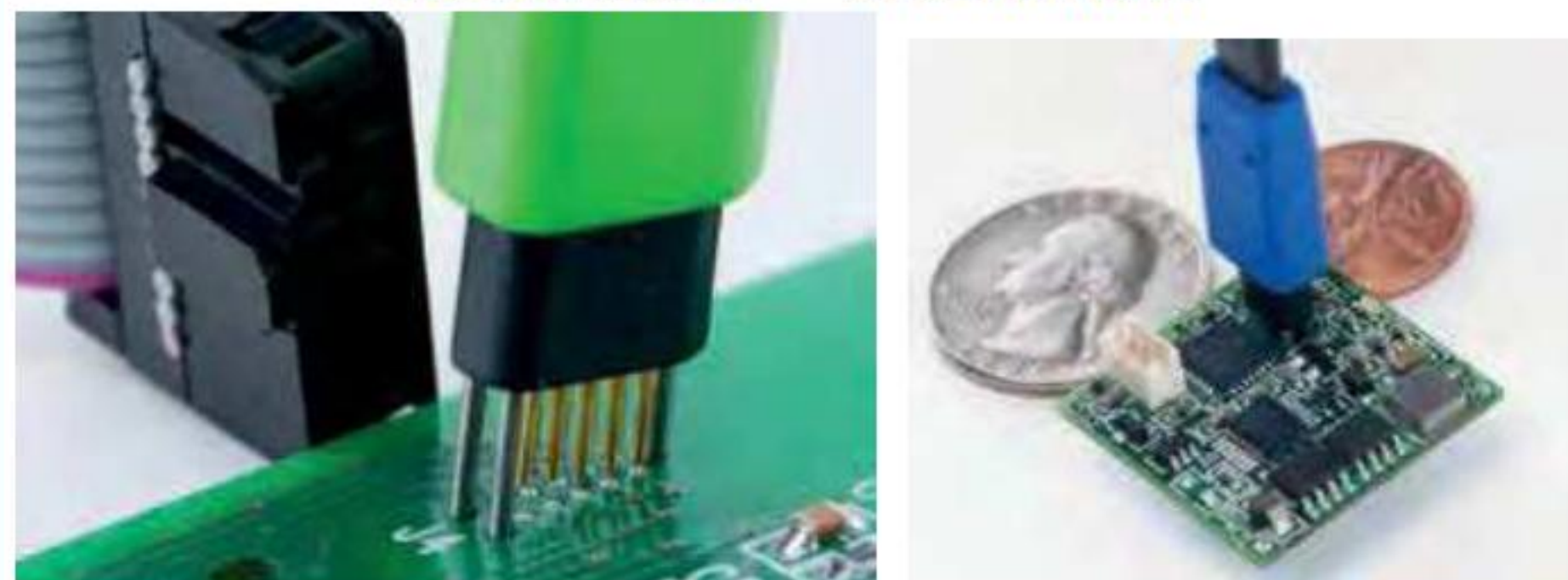


**ORDER YOUR COPY TODAY JUST CALL
01202 880299 OR VISIT www.epemag.com**



JTAG Connector Plugs Directly into PCB!!

No Header! No Brainer!



Our patented range of Plug-of-Nails™ spring-pin cables plug directly into a tiny footprint of pads and locating holes in your PCB, eliminating the need for a mating header. **Save Cost & Space on Every PCB!!**

Solutions for: PIC . dsPIC . ARM . MSP430 . Atmel . Generic JTAG . Altera Xilinx . BDM . C2000 . SPY-BI-WIRE . SPI / IIC . Altium Mini-HDMI . & More

www.PlugOfNails.com

Tag-Connector footprints as small as 0.02 sq. inch (0.13 sq cm)

ESR Electronic Components Ltd 

All of our stock is RoHS compliant and CE approved. Visit our well stocked shop for all of your requirements or order on-line.

We can help and advise with your enquiry, from design to construction.

3D Printing • Cable • CCTV • Connectors • Components • Enclosures • Fans • Fuses • Hardware • Lamps • LED's • Leads • Loudspeakers • Panel Meters • PCB Production • Power Supplies • Relays • Resistors • Semiconductors • Soldering Irons • Switches • Test Equipment • Transformers and so much more...

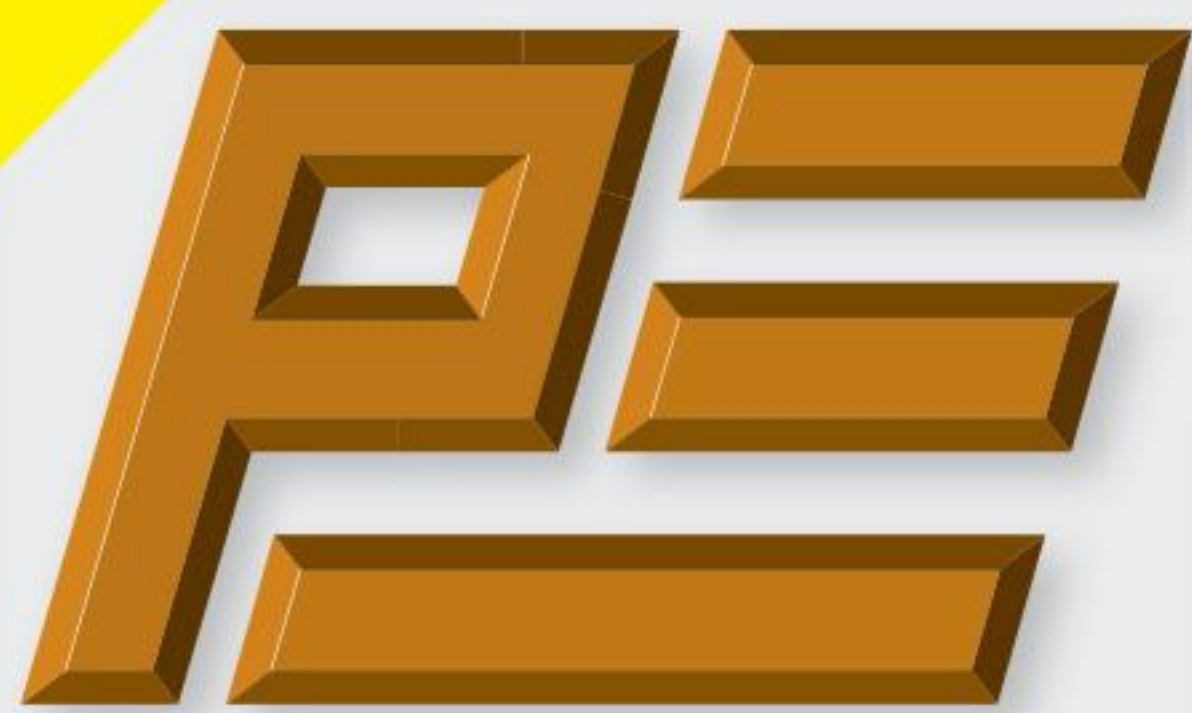
Monday to Friday 08:30 - 17.00, Saturday 08:30 - 15:30



**Station Road
Cullercoats
North Shields
Tyne & Wear
NE30 4PQ**

Tel: 0191 2514363 sales@esr.co.uk www.esr.co.uk

- EPE -
NEW NAME
NEW DESIGN!



Practical Electronics

UK readers **SAVE £1** on every issue



Take out a one-year subscription and save **£10** over the year.

Even better – save **£1** per issue if you subscribe for two years – a total saving of **£24**.

Overseas rates represent exceptional value

- You also:
- Avoid any cover price increase for the duration of your subscription
 - Get your magazine delivered to your door each month
 - Guarantee a copy, even if the newsagents sell out

- Order by:
- Phone or post with a cheque, postal order or credit card
 - Or order online at: www.electronpublishing.com



SUBSCRIPTION PRICES

Subscriptions for delivery direct to any address in:

UK: 6-months £26.99, 12-months £49.85, 24-months £94.99

Europe Airmail: 6-months £30.99, 12-months £57.99, 24-months £109.99

Rest Of The World Airmail: 6-months £37.99, 12-months £70.99, 24-months £135.99

Cheques (in **£ sterling only**) payable to *Practical Electronics* and sent to: Practical Electronics Subscriptions, PO Box 6337, Bournemouth BH1 9EH, United Kingdom

Tel: 01202 087631

Email: pesubs@selectps.com

Also via our online shop at: www.electronpublishing.com

Subscriptions start with the next available issue. We accept MasterCard or Visa.

(For past issues see the Back Issues page.)



DIGITAL SUBSCRIPTIONS

Electronic subscriptions are available from £20.99 for 12 months, more details at: www.electronpublishing.com

SUBSCRIPTION ORDER FORM

- ☐ 6 Months: UK £26.99, Europe £30.99 (Airmail), Rest of the World £37.99 (Airmail)
- ☐ 1 Year: UK £49.85, Europe £57.99 (Airmail), Rest of the World £70.99 (Airmail)
- ☐ 2 Years: UK £94.99, Europe £109.99 (Airmail), Rest of the World £135.99 (Airmail)

To: Practical Electronics Subscriptions
PO Box 6337
Bournemouth BH1 9EH
United Kingdom

Tel: 01202 087631

Email: pesubs@selectps.com

I enclose payment of £
(cheque/PO in £ sterling only)
payable to *Practical Electronics*

☐ Please charge my Visa/Mastercard



My card number is:
Please print clearly, and check that you have the number correct

Card Security Code Valid From Date.....
(The last 3 digits on or just under the signature strip)

Card Ex. Date

Name

Address

Post code Tel.

Email

Subscriptions start with the next available issue.



Defend Your IP, Brand and Revenue Stream

Security Solutions That Are Simple to Add, Hard to Break

Let Microchip help you secure not only your designs, but your brand and revenue stream as well. With two decades of security experience, our experts take the fear out of integrating security and remove the need for costly in-house expertise. Combine that expertise with our secure factories and provisioning services and you'll understand why many top companies trust Microchip's experts to help guide their designs.

From secure encryption to trusted execution environments, find the security implementations that meet your unique needs with our wide range of hardware- and software-based solutions.



Secure your design at www.microchip.com/Secure



Practical Electronics

Publisher's statement

These are exceptional times, and coronavirus is changing how everyone lives and works. Here at Electron Publishing we are working hard to ensure there is as little disruption as possible to the production and distribution of *Practical Electronics*.

Unfortunately, however, some delays in delivering your magazine are inevitable – here is a rough guide to the situation in late March.

UK readers

If you subscribe to *PE* in the UK then we expect little delay or interruption to the delivery of your magazine.

For non-subscription readers in the UK, we sell most of our copies through WHSmith and a few other outlets such as supermarkets and independent newsagents. At present, we expect them to stay open and receive *PE* as before, but we do not control this and hence cannot offer the same reassurance of availability that subscribers enjoy.

If you would like to save money – over a pound per issue – avoid the disappointment of an issue selling out, and more importantly, avoid the risks of leaving your home for physical shopping then perhaps consider subscribing – just visit: <https://bit.ly/pe2020-subs>

European readers

If you subscribe to *PE* in Europe outside the UK, then we expect services to be a little slower, but the delivery route is relatively short and robust, so I hope you will be patient if there are some minor delays. Please do get in touch via email if your copy does not arrive: pe@electronpublishing.com

International readers outside Europe

Life is getting pretty complicated for the underappreciated companies that underpin global supply chains – especially in delivery, freight and post.

For subscribers outside Europe, your copies are still being printed, wrapped and posted. While some of them will arrive in reasonable time, some may not. Copies go to North America, Australasia, India, China and many other locations. Some of you may have to wait several extra weeks for delivery.

We know you pay a hefty premium for international delivery, so for the duration of the current disruption, if you send us your email address, along with your subscription name and address, then we will enrol you in the PDF download system without charge. Your print copy will still arrive, but you won't have an extended wait for the next instalment of a construction project or favourite column.

Digital subscribers

Nothing changes!

Actually, that's not quite true. We will soon be launching a new digital subscriber system for PDF downloads, but this is nothing to do with the current health emergency, and is part of the overall rebuilding of *PE*'s online presence.

For the latest news on *Practical Electronics*, please visit: www.electronpublishing.com

Matt Pulzer
Publisher

Editorial offices

Practical Electronics
Electron Publishing Limited
1 Buckingham Road
Brighton
East Sussex BN1 3RA

Tel 01273 777619
Mob 07973 518682
Fax 01202 843233
Email pe@electronpublishing.com
Web www.epemag.com

Advertisement offices

Practical Electronics Adverts
1 Buckingham Road
Brighton
East Sussex BN1 3RA

Tel 01273 777619
Mob 07973 518682
Email pe@electronpublishing.com

Editor Matt Pulzer
General Manager Louisa Pulzer
Digital subscriptions Stewart Kearn **Tel** 01202 880299
Online Editor Alan Winstanley
Web Systems Kris Thain
Publisher Matt Pulzer

Print subscriptions

Practical Electronics Subscriptions
PO Box 6337
Bournemouth BH1 9EH
United Kingdom

Tel 01202 087631
Email pesubs@selectps.com

Technical enquiries

We regret technical enquiries cannot be answered over the telephone. We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We cannot provide data or answer queries on articles or projects that are more than five years old.

Questions about articles or projects should be sent to the editor by email: pe@electronpublishing.com

Projects and circuits

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in *Practical Electronics* employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD (GFCI) adaptor.

Component supplies

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers. We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

Advertisements

Although the proprietors and staff of *Practical Electronics* take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are bona fide, the magazine and its publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or in inserts. The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture.

Transmitters/bugs/telephone equipment

We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

What a difference a month makes

This time last month I was writing to you about PCBs and speaker drivers. I noted a little inconvenience and possible delays, but other than that, life outside China seemed mostly normal. Very little seems normal now, and we are clearly at the start of a very challenging few months, quite possibly longer.

You will all have concerns and worries, from the health of loved ones and friends to employment security and education. The arrival of a monthly magazine will not be uppermost in your thoughts, and nor should it be. However, I would like to take this opportunity to explain to you, our loyal readership, our preparations for the year and to reassure you that we are well placed to continue publishing and provide you with some welcome alternatives to gloomy news in an uncertain world. Maybe you will even find time to build some of those projects you've been promising yourself!

We are fortunate as a business that all our contributors already work from home and need no training or extra support in delivering their outstanding work. We are in regular contact with our printer and distributors, and while they can see some delays, the systems we have in place will continue to work. Paper and ink will still be delivered, freight planes will still fly and the postal service will do their job.

Opposite, you will find a summary of where we are currently (late March), but the situation is bound to be fluid and for the latest news on *Practical Electronics*, please visit: www.electronpublishing.com

Please support our advertisers!

Selling components to hobbyists has never been a route to great wealth, and independent suppliers will need all the business they can get over the next few months. If you do have a little extra time on your hands and start to wield your soldering iron, please look to our advertisers, for parts – Quasar, ESR, Cricklewood and JPG. You'll miss them if they go!

And this issue?

That's quite enough non-electronic talk, so what do we have for you this month? Lots! From Barry Fox's excellent guide to the best in free software to an exciting new robot buggy project in Phil Boyce's *Make it with Micromite* series, we have more than enough to keep you occupied. Jake explains how to synthesise all sorts of weird and wonderful noises using a simple analogue noise generator and we have the latest XOD project from Julian Edgar.

Take your PIC

In a world of (currently) diminishing choice it's nice to be able to offer something new from our online shop. We have offered PCBs for most of our projects for a long time, but for many of you that is only half a solution. The rise of the now-ubiquitous PIC means that to complete a project you often need a project-specific PCB *and* a programmed PIC. True, we do offer PIC project software as a free download, but for too many builders who have neither the equipment nor sufficient interest in getting into PICs this is not a solution. From April we will address this shortfall and start to sell programmed PICs for *PE* projects. Look out for their arrival in our online shop.

Keep Calm, Carry On and do wash your hands!

Matt Pulzer, Publisher

The Fox Report

Barry Fox's technology column



Welcome to the key-free zone

Most computer software now comes with an activation key. Fair enough, because this helps prevent piracy. But it's a lot less fair if one key cannot activate installations on several same-owner computers (desktop, laptop and rainy-day spare), perhaps throwing up error messages when two are on line at the same time.

Most modern software keys can only be used on one computer, once, and there is no easy option to re-use it legitimately; for example, if the owner has to rebuild a PC after a crash, theft or hardware upgrade. Sometimes a routine OS update will knock out installed software, which then cannot be used on another PC.

First Windows, then macOS

We expect this from Windows, but it is now happening with Macs. The recent upgrade to Catalina killed existing 32-bit software. There was no automated check and warning ahead of installation; just an encouragement to update the OS and then error messages from 32-bit programs, with no option to undo the update. It seems Apple has been taking lessons from Microsoft in how to upset customers.

Another unhappy new trend is to sell software on a monthly or annual subscription, rather than outright purchase; Microsoft's Office 365 or Adobe Photoshop are common examples.

Go key-free

So, unless software promises legitimate re-use of a key; for example, by uninstalling or easy voiding online to de-activate, there is now a real incentive to go key-free, with open-source equivalents that are cash-free (often with the option to make a cash donation to the developers).

The curse of the key and the fact that I own and use multiple computers has driven me to research key-free alternatives. There is a lot of junk out there, with various traps for the unwary – notably, unwittingly downloading software you don't want. I have compiled a list of key-free programs that I have happily used, with no problems (yet). Most are open source, fully free; a few are free, but stripped-down versions of keyed versions with more features.

This list comes with no guarantees and the warning to a) download direct from the developers' sites, not some middleman, and b) think carefully before clicking on 'download' because the good free stuff is sometimes buried amongst not-so-good stuff.

For the purposes of this column, I have deliberately avoided recommending any proprietary software that only works free for a trial period. Free trialling is a good way to buy software because it shows that developers have confidence in their product, but that's not what this key-free list is about.

I have not included free anti-virus software. Recommendations are too risky. But I will say that I have left some PCs protected only by Microsoft's Windows Defender, and not (yet) regretted it.

Office, Mail, photos

Most of what follows is for Windows PCs, but some packages have Mac options.

The longstanding open-source equivalent to Microsoft Office is now called Apache Open Office, see: www.openoffice.org

It does pretty much everything the costly Microsoft packages do, in much the same way, but lacks an equivalent to the Microsoft email client Outlook. Fortunately, Windows 10 comes with a stripped down version of Outlook, called Mail.

Mail lacks some Outlook features, but the wide range of free Google Tools (Calendar, Contacts, Slides, Sheets, Docs, Photos) fills the gap. Contacts makes a good free replacement for now-defunct Cardscan (albeit without Cardscan's clever business card scanning OCR, but not many people use business cards any more). Google Drive provides 15GB of free online/cloud storage, and if you are prepared to spend tedious time mastering the confusing Settings options you can stash limitless photos for free.

Adobe seems hell-bent on pricing Photoshop out of the market, which



**Plastic enclosures
standard & miniature**

www.hammondmfg.com/dwg8.htm

www.hammondmfg.com/1551USB.htm

01256 812812

sales@hammond-electronics.co.uk



is steering serious users towards the extremely powerful open-source, free, rival GIMP (GNU Image Manipulation Program). GIMP takes a bit of learning (like Photoshop) but Adobe's pricing is strong encouragement to make the effort.

Further applications

The free open-source movie editor Shotcut is in many respects the video equivalent of GIMP.

<https://shotcut.org>

Open-source Handbrake efficiently transcodes video (crushes file sizes, processes and converts formats) for free.

<https://handbrake.fr>

Where Handbrake can't cope with a video processing job, then Avidemux probably can. For instance, Avidemux can stitch small video files together.

<https://sourceforge.net/projects/avidemux>

Audacity is a wonderful free open-source tool for editing sound; in many respects it is the audio equivalent of Shotcut. It also enables the capture of streams and inputs that the computer is playing, which can be more useful

than the music industry would wish.

www.audacityteam.org

Likewise, OBS (Open Broadcaster Software) is excellent free, open-source software for capturing and streaming video.

<https://obsproject.com>

By far the best all-round program for playing audio and video files is free open-source VLC.

www.videolan.org

The only thing VLC has failed me on (despite my adding add-ons) is playing Blu-ray movies from a Blu-ray drive. Although the appearance is a bit crude, the free version of Leawo Blu-ray player will usually do the trick.

www.leawo.com/blu-ray-player

Downloading multimedia files can be a nuisance. I have found that JDownloader eases the pain. In fact, you may be surprised at just what audio and video streams it can download.

<https://jdownloader.org>

When files are too big to attach to an email, or rejected by the recipient's system, some people use the free tier

of Dropbox. I prefer the 2GB free tier of WeTransfer, but do try both.

www.dropbox.com

<https://wetransfer.com>

One unhappy by-product of spending too much time with a computer is the way it fills up with duplicate files. The best free tool I have found for thinning them out is Duplicate Cleaner Free.

www.digitalvolcano.co.uk/dcdownloads.html

If disaster strikes and your computer is wiped out by a crash, malware or update, you will hope you have a recent full system backup. By far the most reliable backup program of many I have tried is Macrium Reflect. The free version makes full system backups, which is all most people need to sleep easy.

www.macrium.com/reflectfree

Doubtless some readers will already be fuming over software that I have failed to mention and which they feel is better than the stuff I have mentioned. If so, let's hear from them and share the benefits.

Barry Fox, FBKS (Fellow, International Moving Image Society)



Fluke/Philips PM3092 Oscilloscope
2+2 Channel 200MHz Delay TB,
Autoset etc – £250

STEWART OF READING

17A King Street, Mortimer, near Reading, RG7 3RS

Telephone: 0118 933 1111 Fax: 0118 933 2375

USED ELECTRONIC TEST EQUIPMENT

Check website www.stewart-of-reading.co.uk

(ALL PRICES PLUS CARRIAGE & VAT)

Please check availability before ordering or calling in



HP 54600B Oscilloscope
Analogue/Digital Dual Trace 100MHz
Only £75, with accessories £125

LAMBDA GENESYS	PSU GEN100-15 100V 15A Boxed As New	£400	Marconi 2305	Modulation Meter	£250
LAMBDA GENESYS	PSU GEN50-30 50V 30A	£400	Marconi 2440	Counter 20GHz	£295
IFR 2025	Signal Generator 9kHz – 2.51GHz Opt 04/11	£900	Marconi 2945/A/B	Communications Test Set Various Options	P O A
IFR 2948B	Communication Service Monitor Opts 03/25 Avionics	P O A	Marconi 2955	Radio Communications Test Set	£595
IFR 6843	Microwave Systems Analyser 10MHz – 20GHz	P O A	Marconi 2955A	Radio Communications Test Set	£725
R&S APN62	Syn Function Generator 1Hz – 260kHz	£295	Marconi 2955B	Radio Communications Test Set	£800
Agilent 8712ET	RF Network Analyser 300kHz – 1300MHz	P O A	Marconi 6200	Microwave Test Set	£1,500
HP8903A/B	Audio Analyser	£750 – £950	Marconi 6200A	Microwave Test Set 10MHz – 20GHz	£1,950
HP8757D	Scaler Network Analyser	P O A	Marconi 6200B	Microwave Test Set	£2,300
HP3325A	Synthesised Function Generator	£195	Marconi 6960B	Power Meter with 6910 sensor	£295
HP3561A	Dynamic Signal Analyser	£650	Tektronix TDS3052B	Oscilloscope 500MHz 2.5GS/s	£1,250
HP6032A	PSU 0-60V 0-50A 1000W	£750	Tektronix TDS3032	Oscilloscope 300MHz 2.5GS/s	£995
HP6622A	PSU 0-20V 4A Twice or 0-50V 2A Twice	£350	Tektronix TDS3012	Oscilloscope 2 Channel 100MHz 1.25GS/s	£450
HP6624A	PSU 4 Outputs	£400	Tektronix 2430A	Oscilloscope Dual Trace 150MHz 100MS/s	£350
HP6632B	PSU 0-20V 0-5A	£195	Tektronix 2465B	Oscilloscope 4 Channel 400MHz	£600
HP6644A	PSU 0-60V 3.5A	£400	Farnell AP60/50	PSU 0-60V 0-50A 1kW Switch Mode	£300
HP6654A	PSU 0-60V 0-9A	£500	Farnell XA35/2T	PSU 0-35V 0-2A Twice Digital	£75
HP8341A	Synthesised Sweep Generator 10MHz – 20GHz	£2,000	Farnell AP100-90	Power Supply 100V 90A	£900
HP83630A	Synthesised Sweeper 10MHz – 26.5 GHz	P O A	Farnell LF1	Sine/Sq Oscillator 10Hz – 1MHz	£45
HP83624A	Synthesised Sweeper 2 – 20GHz	P O A	Racal 1991	Counter/Timer 160MHz 9 Digit	£150
HP8484A	Power Sensor 0.01-18GHz 3nW-10µW	£75	Racal 2101	Counter 20GHz LED	£295
HP8560E	Spectrum Analyser Synthesised 30Hz – 2.9GHz	£1,750	Racal 9300	True RMS Millivoltmeter 5Hz – 20MHz etc	£45
HP8563A	Spectrum Analyser Synthesised 9kHz – 22GHz	£2,250	Racal 9300B	As 9300	£75
HP8566B	Spectrum Analyser 100Hz – 22GHz	£1,200	Solartron 7150/PLUS	6½ Digit DMM True RMS IEEE	£65/£75
HP8662A	RF Generator 10kHz – 1280MHz	£750	Solartron 1253	Gain Phase Analyser 1mHz – 20kHz	£600
Marconi 2022E	Synthesised AM/FM Signal Generator 10kHz – 1.01GHz	£325	Solartron SI 1255	HF Frequency Response Analyser	P O A
Marconi 2024	Synthesised Signal Generator 9kHz – 2.4GHz	£800	Tasakago TM035-2	PSU 0-35V 0-2A 2 Meters	£30
Marconi 2030	Synthesised Signal Generator 10kHz – 1.35GHz	£750	Thurlby PL320QMD	PSU 0-30V 0-2A Twice	£160 – £200
Marconi 2023A	Signal Generator 9kHz – 1.2GHz	£700	Thurlby TG210	Function Generator 0.002-2MHz TTL etc Kenwood Badged	£65



HP/Agilent HP 34401A Digital
Multimeter 6½ Digit £325 – £375

HP33120A
HP53131A
HP53131A
Audio Precision
Datron 4708
Druck DPI 515
Datron 1081
ENI 325LA
Keithley 228
Time 9818

Function Generator 100 microHz – 15MHz
Universal Counter 3GHz Boxed unused
Universal Counter 225MHz
SYS2712 Audio Analyser – in original box
Autocal Multifunction Standard
Pressure Calibrator/Controller
Autocal Standards Multimeter
RF Power Amplifier 250kHz – 150MHz 25W 50dB
Voltage/Current Source
DC Current & Voltage Calibrator

£350
£600
£350
P O A
P O A
£400
P O A
P O A
P O A
P O A



Marconi 2955B Radio
Communications Test Set – £800

Joy or dread: do we get a choice?

Techno Talk

Mark Nelson

Probably not, unless you are ultra-careful. There's no gain without pain and that's the theme of this month's article. But there may be light at the end of the tunnel, so let's dish out the bad news first and then close on a more optimistic note. Buckle up, hold tight and off we go...

This year's CES (Consumer Electronics Show), held in Las Vegas, retained its rank as the world's premier showcase where next-generation innovations are introduced to the marketplace. Included were several competing smart home systems, based on IoT (Internet of Things) platforms, differing from one another in only minor details. Unfortunately, as one observer noted, no homeowner can afford to invest in multiple smart platforms, meaning that most of this year's offerings will likely not be around next year.

Reasons to be cheerful, one, two, three

Disappointingly, many of the far-from-cheap innovations might strike consumers as problems looking for a solution. Do people really need Bluetooth skillets that track nutritional info on the food you put in them and use heat sensors to figure out where the pan is too warm or cold? The name was good though: 'SmartyPans'. Does anyone actually need an IoT-enabled cat litter tray that alerts your smartphone when *Chairman Miao* (<http://bit.ly/pe-may20-miao>) has done his/her business? Visit: www.lavviebot.com if you do.

On the other hand, some IoT applications sort of make sense. A fingerprint-activated front-door lock for your home that also integrates with Amazon Alexa and Google Assistant smart speakers might appeal to some, particularly as it is claimed to be easy to install and is priced 'affordably' at \$249. If tempted, search on YouTube for 'Kwikset Halo Touch smart lock'.

If you're into smart speakers, how about one with a touchscreen that wraps around its cylindrical body? Go to YouTube and search for 'Royole Mirage Cleer'.

Reasons to be fearful, one, two, thousands or more

Why speak of suffering and sorrow, when IoT devices can make life significantly more convenient? Because IoT can make life more hazardous as well,

thanks to thoughtless and careless interfacing. Plenty of domestic IoT products are as safe to use as a chocolate teapot, simply because their minimal security provides hackers uncontrolled access to your home network.

Early adopters paid the price of buying IoT gadgets that were totally insecure. Take, for example, one brand of home security CCTV camera. Not only was it a surveillance camera, but it also doubled as a baby monitor. As it turned out, anyone able to find the IP address of the devices could easily take control of it, forwarding overheard speech to their own PCs. The cameras also transmitted their owners' login information over the Internet as clear, readable text without any encryption. In the US, one hacker got into a wireless camera system and threatened to kidnap the family's baby.

The **Smarthomestarter.com** website relates how garage door openers can be hacked too if the connected Wi-Fi network has weak security attributes. Bingo – burglars can enter your home via the garage while you're away. Alternatively, they can stay at home and instead access your PC to snoop into your personal data and create mischief or havoc playing with other smart devices connected to your network. I was also going to mention how the IoT-enabled 'Vibratissimo Panty Buster' 'adult' toy could be hacked remotely to inflict unexpected effects on their owners, but fortunately I have run out of space! Most manufacturers are now taking IoT security more seriously, but plenty of insecure products remain in use and perhaps on sale. In the meantime, most IoT users have no idea whether their smart home network is now vulnerable or not.

From out of thin air

Good news: yet another 'free electricity' device has been invented. This one is called Air-gen, and unlike other renewable energy sources, it works indoors as well as outside and does not require sunlight or wind. So how does Air-gen work and who invented it?

The kudos goes to scientists at the University of Massachusetts Amherst in the US. Electrical engineer Jun Yao and microbiologist Derek Lovley teamed up to develop a device that uses natural protein to create electricity from moisture in the air, a new technology they say could have significant implications for the future of renewable energy, climate change and the future of medicine.

Their air-powered generator is constructed using a thin film (less than 10µm thick) of protein nanowires that are produced naturally by the microbe *Geobacter sulfurreducens*, which occurs in the mud in some riverbeds. A degree of atmospheric humidity is essential and when the protein nanowires (which are electrically conductive) combine with water, they produce a voltage gradient that can be connected to electrodes, enabling electrical current to be generated. Water vapour is naturally present in the atmosphere, even in areas with extremely low humidity.

Commercial prospects

Although the researchers concede that the current generation of Air-gen devices can power only small electronic circuits, they expect to bring the invention to commercial scale soon. Their plans include developing a small Air-gen patch that can power electronic wearables such as health and fitness monitors and smart watches, which would eliminate the requirement for traditional batteries. They also hope to develop Air-gens to power cell phones to eliminate periodic charging.

Says Yao, 'This is just the beginning of a new era of protein-based electronic devices. The ultimate goal is to make large-scale systems. For example, the technology might be incorporated into wall decorations that could help power your home. Or, we may develop stand-alone air-powered generators that supply electricity at off-grid locations. Once we get to an industrial scale for wire production, I fully expect that we can make large systems that will make a major contribution to sustainable energy production.'

Win a Microchip MPLAB ICD 4 In-Circuit Debugger

Practical Electronics is offering its readers the chance to win a Microchip Technology MPLAB ICD 4 In-Circuit Debugger (DV164045) – *and even if you don't win, receive a 20%-off voucher, plus free shipping for an MPLAB ICD 4.*

The new MPLAB ICD 4 introduces a faster processor and increased RAM to deliver up to twice the speed of ICD 3 for the in-circuit debugging of PIC microcontrollers and dsPIC digital signal controllers. The MPLAB ICD 4 also introduces a wider target voltage range and an optional 1A of current via an external power supply.

For maximum flexibility, MPLAB ICD 4 features a selectable pull-up / pull-down option to the target interface and programmable adjustment of debugging speed for greater productivity. The MPLAB ICD 4's significant improvement in speed is accomplished through a 32-bit MCU running at 300MHz. Faster processing, together with an increased buffer memory of 2MB, results in a product that is up to twice as fast as its predecessor.

Microchip's MPLAB ICD 4 is easy to use and supports many of the PIC microcontrollers and dsPIC digital signal controllers in Microchip's portfolio through the MPLAB X Integrated Development Environment (IDE).

This simplifies the design process for customers when they choose to migrate from one PIC MCU to another to meet the needs of their application.

The MPLAB ICD 4 connects to the PC using a high-speed USB 2.0 interface and is connected to the target with a debugging connector which is also compatible with the MPLAB ICD 3 or MPLAB REAL ICE In-Circuit Emulator systems. The MPLAB ICD 4 also works with JTAG interfaces.

**Worth
\$249.95
(approx £193)
each**

The MPLAB ICD 4 offers faster and more flexible real-time in-circuit debugging:

- Supports many PIC microcontrollers and dsPIC DSCs
- ×2 faster than ICD 3
- Reduced wait time improves debugging productivity
- Simplifies migration between PIC MCUs

**Free-to-enter
competition**



Microchip
MPLAB ICD 4
In-Circuit Debugger

How to enter

For your chance to win a Microchip MPLAB ICD 4 In-Circuit Debugger or receive a 20%-off voucher, including free shipping, enter your details in the online entry form at:

<https://page.microchip.com/PE-ICD-4.html>

Closing date

The closing date for this offer is 30 April 2020.

January 2020 winner

Brian Fairchild

He won a Microchip MPLAB PICKit 4 In-Circuit Debugger



Net Work

Alan Winstanley

This month, *Net Work* looks at the jargon-loaded mess that greets TV users when trying to decide what to watch and how to record it.

Hutber's Law suggests that, 'improvement means deterioration,' and good examples might include some aspects of Britain's digital TV service, coupled with an apparent dearth of dependable personal video recorder (PVR) machines for storing programmes on a hard disk. This month's *Net Work* takes another look at Freeview, Britain's Live on Demand digital terrestrial TV service that is beamed for free into millions of homes via their aerials. Scores of standard definition and HD programmes are aired through half a dozen multiplexes, and some 20 million viewers currently suffer the endless need to retune their receivers due to the '700MHz clearance' as bandwidth gets sold off for mobile telephony, and TV channel numbers keep being shuffled around or dropped altogether.

Guide to jargon

These days, having an on-screen EPG (Electronic Programme Guide) isn't enough, so a Freeview app, downloadable separately, offers viewers an EPG on their smartphones or tablets. The app has been roundly criticised for merely being something that points to all the other 'on-demand' apps that would have to be installed separately in any case. Many viewers expected a seamless live TV and on-demand TV service streamed to their mobile device: '[The Freeview app] is just visual TV pages and you have to download another app per broadcaster to

watch anything,' said one, but it works well enough for many other users. You can try the online Freeview EPG at: www.freeview.co.uk/tv-guide but you may have to download the Freeview mobile app or log into the respective players from the main broadcasters.

The jargon gets worse – not forgetting the industry mix-up over 'HD Ready' and 'Full HD', and ordinary consumers can be forgiven for confusing 'live TV on demand' with 'on-demand' or 'catch-up' TV, expressions that are used interchangeably. Free services for satellite dish users are offered by Freesat, and then there's Freeview Play, which provides live TV through an antenna plus catch-up TV, which needs broadband and a Freeview Play TV or recorder to host the catch-up player apps. Over half of all new TV sets now have Freeview Play built in.

Alternatively, a Youview recorder adds pause and future programme recording, along with 7-day catch-up TV. Some Youview TVs, such as certain Sony Bravia Android TVs can connect to an external hard disk to store recordings.

As for planning one's TV entertainment, things start to unravel: Youview offers a mobile app it describes as: 'a perfect companion to your [Youview] box. It lets you browse the [TV] guide and set recordings all on the go. You can even play available programmes straight from the guide.' However, those who like this mobile app will shortly be disappointed: Youview is dropping it entirely on 31 March,

stating that they are refocusing on working with their industry partners (BT, TalkTalk, Humax and Sony) instead of dealing with the end-users who pay for it all in the first place. Only BT TV users have an app that allows them to set up recordings remotely.

Withdrawal symptoms

It's becoming harder for TV users to confidently make buying decisions that are reasonably future-proof. Many of us already know the feeling of being short-changed when apps or services are withdrawn or equipment is rendered obsolete almost overnight: the author's Samsung Smart TV started to suffer these 'withdrawal symptoms' straight out of the box, and it currently sulks when trying to launch BBC iPlayer or My5 using its native apps, to the extent that last night I gave up on it altogether.

Online user reviews are handy for highlighting emerging problems with set-top boxes and digital TV recorders before you buy. The market-leading DTV-recorder maker Humax has been well regarded for its PVRs in the past and currently lists just one Youview box, the DTR-T2000. Many buyers seem delighted with it, but a worrying number cite very noisy hard disks, fans and clunky menus, along with a shopping list of lock-ups and other problems. Strangely, Humax was out of stock at the time of writing, although many refurbished ones were available from other online sources.

The other mainstream choice of PVR seems to be the Humax Freeview Play recorder FVP-5000 (500GB-2TB, Wi-Fi/Ethernet). Browsing user feedback on Amazon, many recent buyers praised its performance but others equally slated its slow response, complaining of noisy hard drives again, heating problems, very slow EPG interfaces and sub-standard apps.

To err is Humax

These negative 'vibes' bring me to problems I've had with my own Freeview recorder, a Humax HDR-Fox T2 that over the years has been one of the



The Youview DTR-T2000 by Humax plays digital TV, 7-day catch-up TV and scheduled recordings. The Youview mobile app is being discontinued on 31 March and will no longer be available in the App store or Google Play.



The HD HomeRun network-attached TV receiver promises live TV all around the home. Twin and quad tuners are available, along with an extra paid-for PVR solution.

most rewarding devices I ever owned. This 2011-era box has the usual pause/rewind features controlling live TV, its searchable EPG has been superior to many and series recordings have generally worked perfectly, allowing me to binge-watch popular TV series many months later. Sadly, Humax failed to deliver on some promised catch-up apps, which would be a sign of things to come, and its limited choice of Internet-powered apps has been mediocre. Nevertheless, this popular recorder played a key role in our in-house entertainment, but signs of trouble emerged recently when the player suddenly started to 'green screen' on the TV's HDMI port. The player did the same when tested on other TVs. The excellent online forum **Hummy.TV**, probably the best Humax resource out there, suggested that I was not alone and it was probably an HDMI handshaking problem. Eventually, the HDMI failed altogether, rendering the disk inaccessible unless a fuzzy Scart lead was used instead. The quest to fix it would not end well.

There may be trouble ahead

The next task was to back up some cherished recordings before the recorder failed altogether. Copying them onto a fan-cooled, external EXT3-formatted hard drive would be a long and laborious job, but undeterred I queued up a large batch of files and left the PVR running overnight. That was my first mistake: checking it over, I wasn't convinced that this had been successful so I then tried using FTP to copy files over the LAN onto a PC

instead, another overnight session. Next morning, feeling very smug I marvelled at a PC drive full of files but then I hit another problem: I couldn't do anything with them. My PC video software complained of, 'no PIDs when trying to open transport system' among several other cryptic messages.

Guided by users on **Hummy.TV**, I learned that by default the Humax PVR encrypts and locks all recordings to that individual PVR. The consensus was to copy them to a USB drive (my heroic FTP effort had been in vain) which decrypts them, but over the next day or two, things started unravelling and suddenly the PVR file

system got stuck into its infamous 'delete loop', a warning sign of file system corruption that I had suffered before.

To repair *that* problem, I tried to Telnet into the PVR using Putty and run a disk-repair option with custom PVR firmware provided by the Humax user community, another long job, which on the surface seemed successful. Long story short, unfortunately the very recordings that I hoped to rescue were damaged in the process as their corresponding .hmt files became corrupted when I was FTPing them to and fro, and the PVR stubbornly refused to play any of my favourite recordings. I could reformat the disk, losing everything and maybe FTP the original files back again, or I could spend days trying another technical approach that would appeal to power users with time on their hands! And then the HDMI port failed anyway.

Here comes the future

Tackling such a challenge becomes a hobby in itself, but sadly the repair of this device has been relegated to a rainy day. The search was on for a replacement Freeview recorder. I outlined earlier some choices that buyers currently face when shopping for a new Freeview PVR. Boxes are mostly made by Humax and seem to boil down to an (out of stock) Humax-built Youview unit with no mobile app, or a Freeview Play unit which has some worrying reviews about usability. Issues with EPGs and missing search features add to the dilemma. Overall, none of the contenders seemed to come close to the well-built Humax HDR-FOX T2

dating back to my December 2011 column; it seems that today's PVRs are becoming lightweight, disposable bits of kit to be written off after a few short years.

Network Freeview receiver

Late last year, for the first time, more than 50% of UK homes subscribed to a streaming video service like Amazon Prime and Netflix, demonstrating the unstoppable move towards video entertainment delivered by broadband. Another approach to consider is a dedicated network-attached Freeview adaptor. My thanks to reader Brian Hoskins who emailed following my December 2019 column when I discussed some Freeview HD TV woes. Brian says: 'Have you considered installing a network Freeview receiver? I use the HD HomeRun receiver, which receives Freeview channels via my home aerial (quad tuner) and then distributes the feed over my home network. I can pick it up on my mobile phone, my PC and even other televisions in and around my home. To receive it on televisions you need a cheap device such as an Amazon Fire TV Stick with the HD HomeRun app installed on it. The beauty is you can receive HD channels and display them on your TV regardless of its own Freeview reception capabilities, even if it can't display the broadcast at full resolution. If your TV is in Wi-Fi range of your home network, you're good to go. You can even pick up your home Freeview feed from anywhere in the world by extending the idea a bit. A PLEX server can, for example, use a DVR. It's compatible with the HD HomeRun, and that means I can access my PLEX server from anywhere in the world and view my home Freeview feed. I can even view a live TV guide and set PLEX to record programmes for me. I can watch my home feed while away from home on my mobile, a laptop PC, or even another television provided I have a device that can host the PLEX client (Fire TV again).'

Brian kindly sent a video demonstrating his HD HomeRun box and how it sits discretely out of sight, needing just power, an antenna and an Ethernet cable. Its US maker, Silicon Dust, also offers a low-cost subscription-based DVR service with 14-day EPG (it's a 24-hour EPG out of the box), which records to your NAS and can be viewed on any smart device around the home, they say. The HD HomeRun sounds an excellent way of viewing TV that would appeal to the home network enthusiast. Devices tuned for other countries are available; not available in the UK

PoLabs

For more information or software download please visit 

www.poscope.com/epe

PoKeys Connect, Control



- USB
- Ethernet
- Web server
- Modbus
- CNC (Mach3/4)
- IO
- PWM
- Encoders
- LCD
- Analog inputs
- Compact PLC

Stepper motor drivers Drive



- up to 256 microsteps
- 50 V / 6 A
- USB configuration
- Isolated
- up to 32 microsteps
- 30 V / 2.5 A

PoScope Mega1+ PoScope Mega50 Measure



- up to 50MS/s
- resolution up to 12bit
- Lowest power consumption
- Smallest and lightest
- 7 in 1: Oscilloscope, FFT, X/Y, Recorder, Logic Analyzer, Protocol decoder, Signal generator



Friends Against Scams is designed to encourage grassroots recognition of fraud, including online scams, as well as supporting victims of scams.

is a 'Servio' PVR version. Thanks again to Brian for the tip: more details of the HD HomeRun are on the Silicon Dust website at: www.silicondust.com

Finally this month

A scheme called 'Friends against Scams' produced by Britain's National Trading Standards scam team is designed to empower people at grass roots level to take a tough stand against common forms of fraud, including smishing and phishing scams, bogus lottery, pharma and fake goods scams and Internet romance fraud. It has produced a useful 20-minute video explaining various ruses used by scammers, and also helps individuals to identify and help vulnerable people who may have fallen victim to them. You can become a Friend against Scams online at: www.friendsagainstscams.org.uk – and you can go further by volunteering to be a SCAMchampion, helping your local community to beat the scammers.

During recent storms that swept across Britain, a 400-year-old oak tree blew down into the path of two cars that were driving in opposite directions. By co-incidence both cars were Teslas, and one car's automatic braking system detected the falling tree ahead and brought it to an emergency halt with milliseconds to spare. The tree fell onto both cars' bonnets (hoods) instead of the passenger compartments and Tesla's array of safety features saved their occupants' lives, they say.

Lincolnshire Police in Britain has added two new members to its crime squad, dedicated to fighting cyber crime and digital fraud. Police Dogs Flurry and Henry are being trained to sniff out old hard drives, discarded SIM cards, phones and other electronic gadgetry. Searches that would take days for humans can now be done

in an hour, say Police Specialist Ops dog handlers. Meet Flurry on: <https://youtu.be/sEbXsuaolyY>

A gang of eight crooks from Hampshire in southern England were jailed for more than 18 years in February after they netted over £350,000 (\$455,000) by accessing over 2,000 BT customer accounts. They created call divers and redirected customers' emails. Then, using stolen bank and PayPal details they bought luxury goods online for delivery to their own addresses. The true scope of the fraud is likely to be much higher and probably runs nationwide, Portsmouth Police think.

BT Openreach is trialling its proposed new VoIP service designed to replace Britain's PSTN telephony by 2025. How IP telephony is handled by equipment that relies on PSTN links such as alarms and care call systems has yet to be fully assessed. As the industry slowly migrates towards FTTP, ultra high-speed fibre could eventually be delivered direct to UK consumers and small businesses by independent suppliers such as Internetty (www.internetty.uk), which plans to deliver up to 1Gb hyperfast broadband in select areas.

BBC Television's 'Click' gadget program has questioned whether some popular 'food hack' videos posted onto Facebook are actually any good or simply (whisper) click bait instead. Their verdict is shown in the BBC's 'Fake Bakes' report at: <http://bit.ly/pe-may20-gard1>. The world of gardening 'hack' videos is similarly scrutinised by MiGardener, see: <http://bit.ly/pe-may20-gard2>

See you next month for more from *Net Work!*

The author can be reached at:
alan@epemag.net

WIRELESS FOR THE WARRIOR

by LOUIS MEULSTEE

THE DEFINITIVE TECHNICAL HISTORY OF RADIO COMMUNICATION EQUIPMENT IN THE BRITISH ARMY

The *Wireless for the Warrior* books are a source of reference for the history and development of radio communication equipment used by the British Army from the very early days of wireless up to the 1960s.

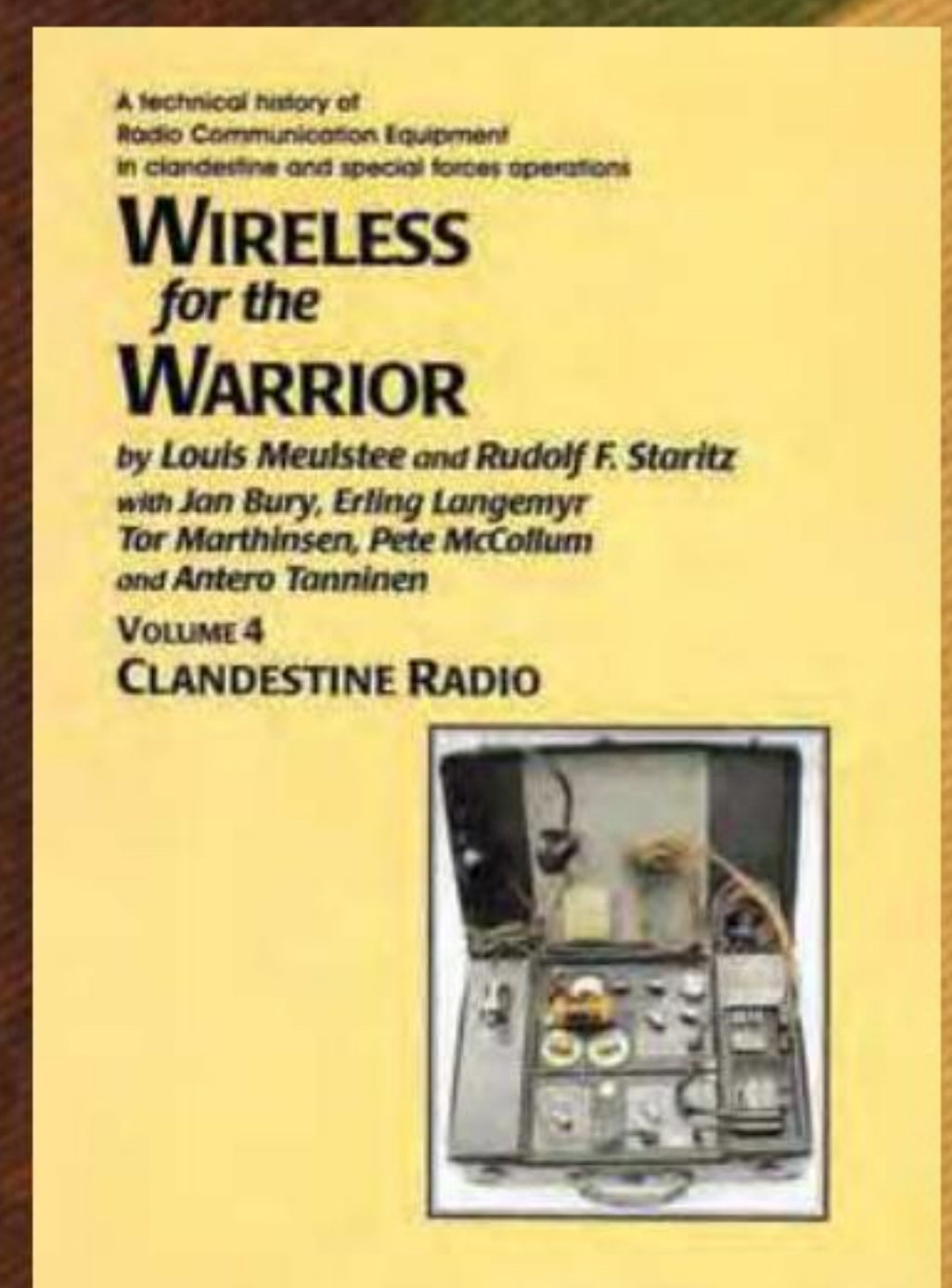
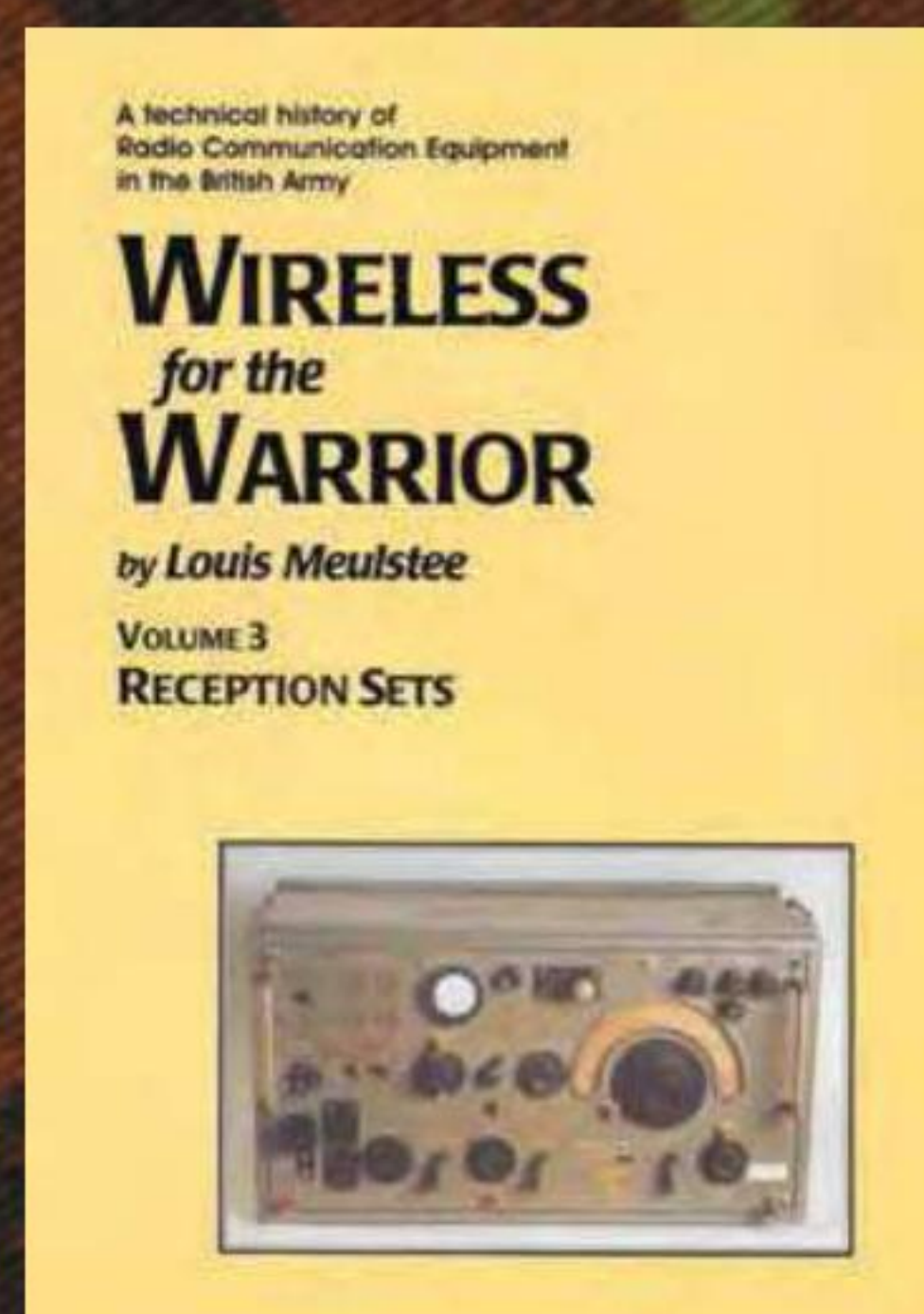
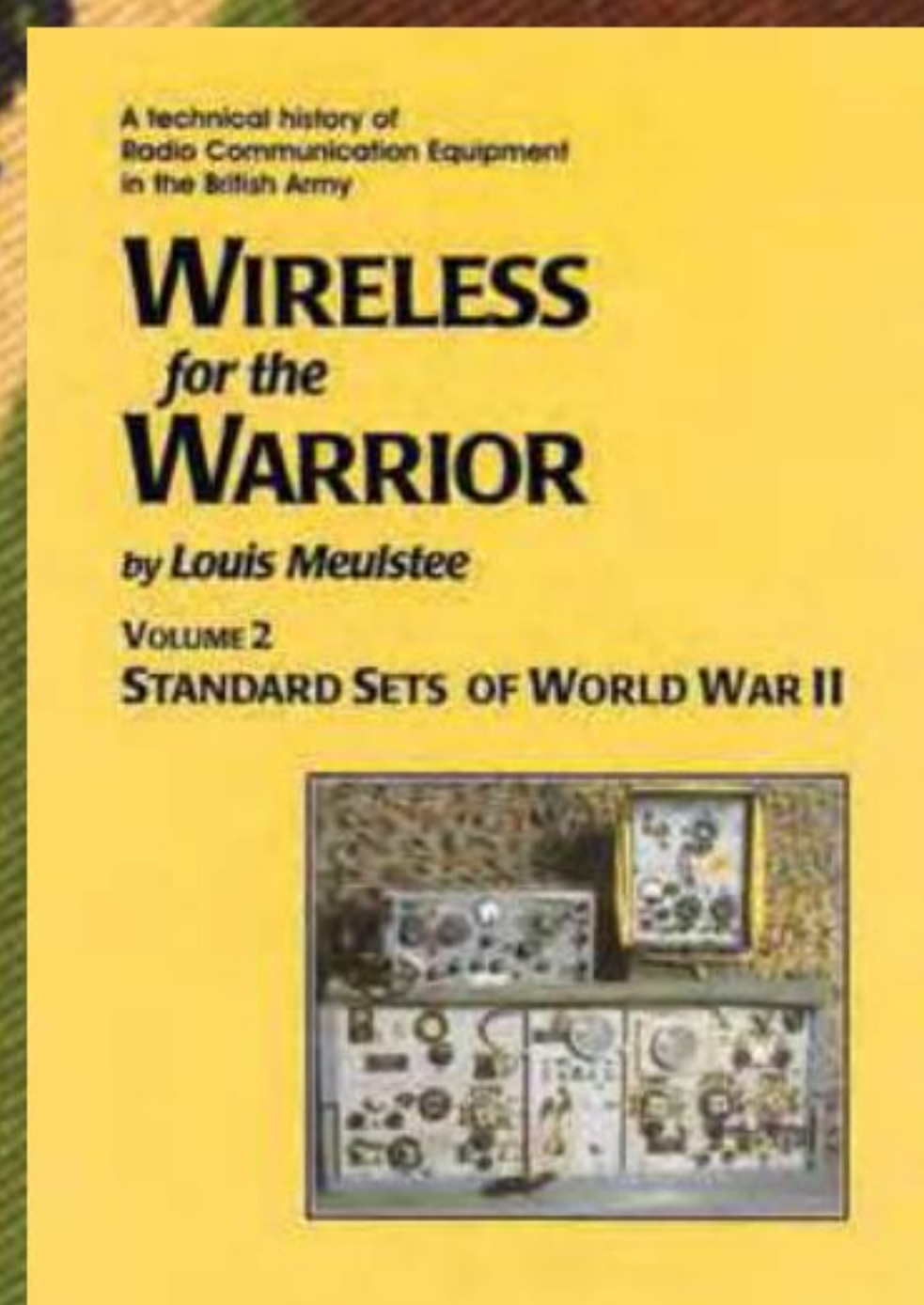
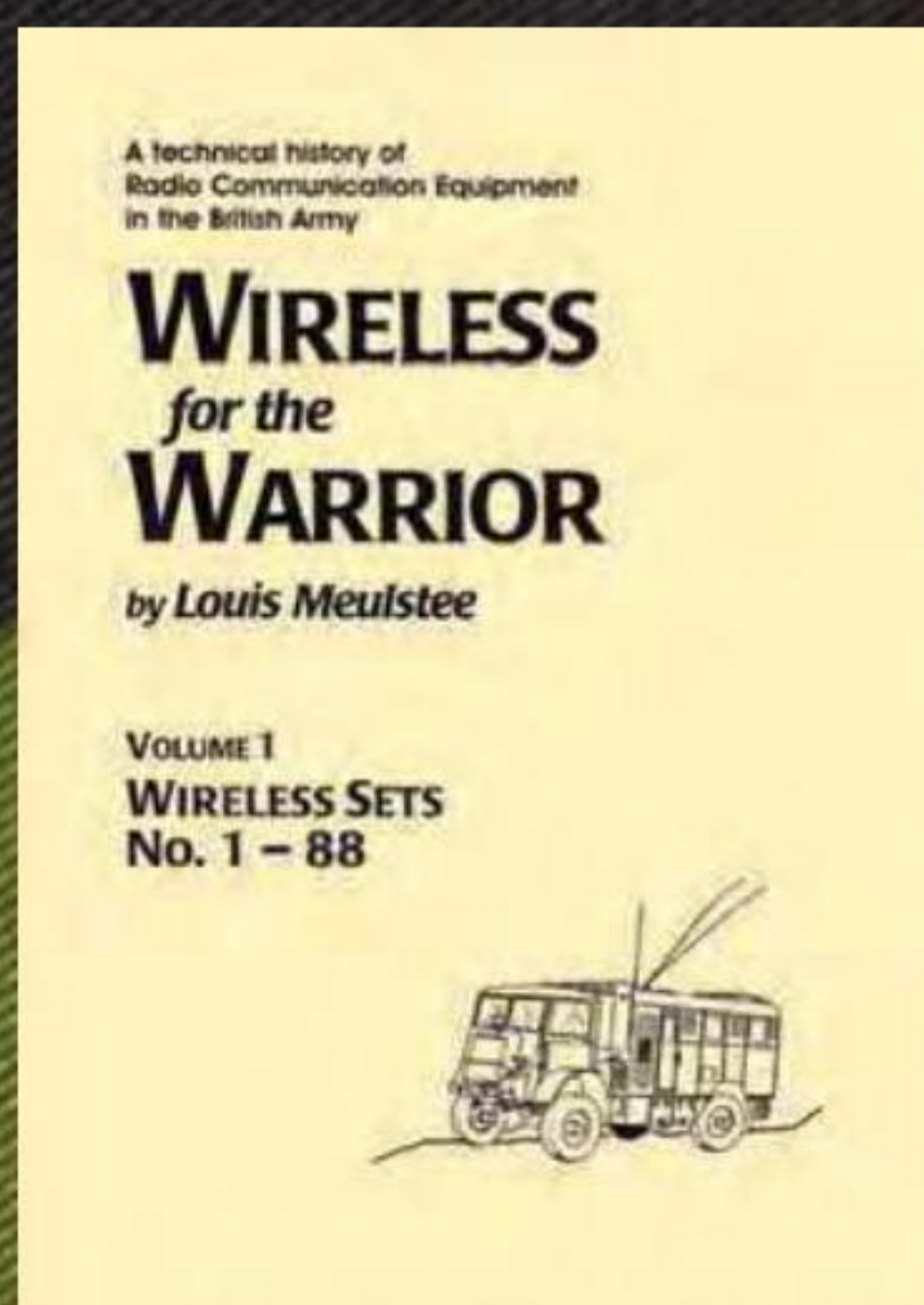
The books are very detailed and include circuit diagrams, technical specifications and alignment data, technical development history, complete station lists and vehicle fitting instructions.

Volume 1 and *Volume 2* cover transmitters and transceivers used between 1932-1948. An era that starts with positive steps taken to formulate and develop a new series of wireless sets that offered great improvements over obsolete World War I pattern equipment. The other end of this

timeframe saw the introduction of VHF FM and hermetically sealed equipment.

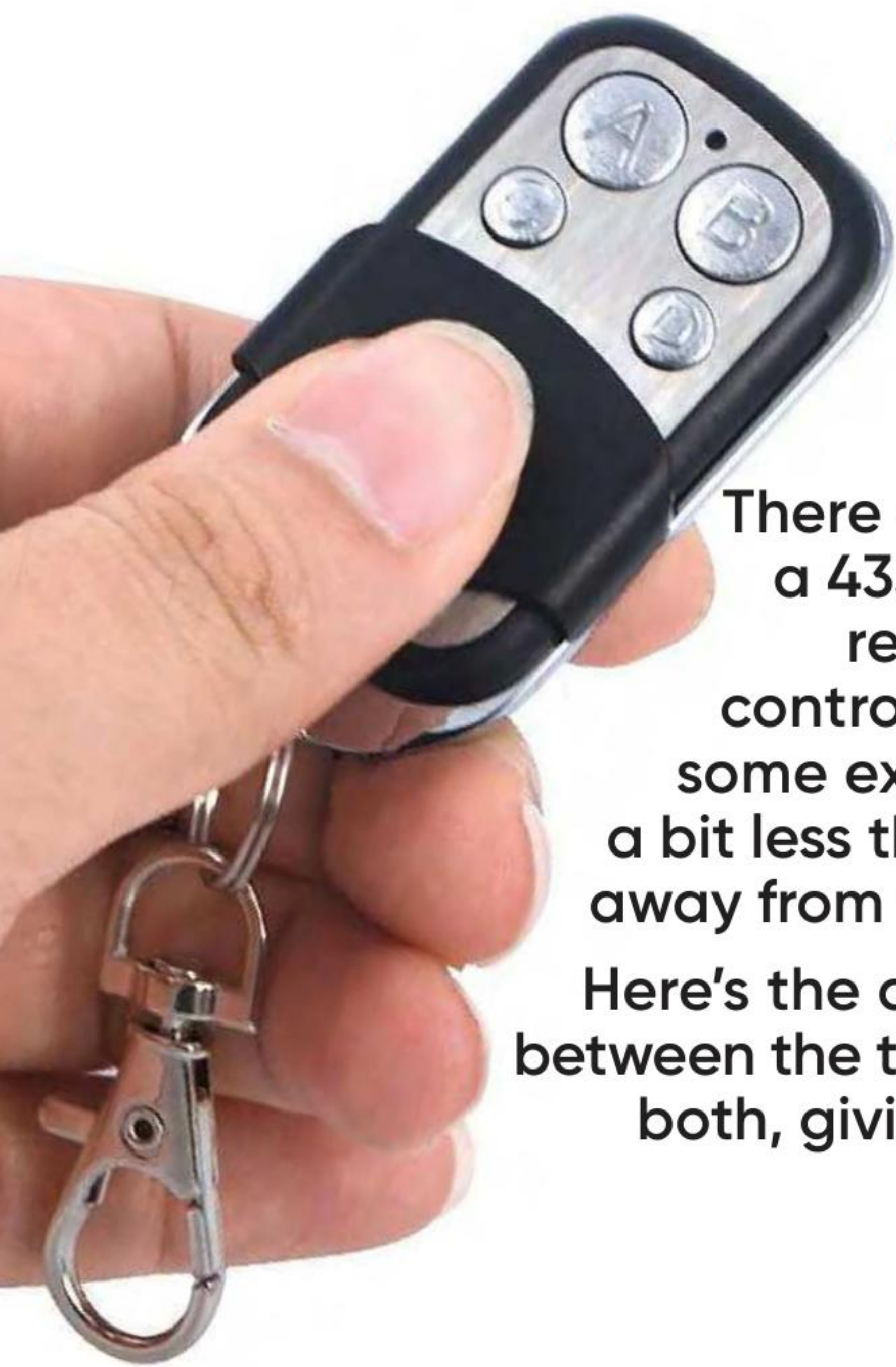
Volume 3 covers army receivers from 1932 to the late 1960s. The book not only describes receivers specifically designed for the British Army, but also the Royal Navy and RAF. Also covered: special receivers, direction finding receivers, Canadian and Australian Army receivers, commercial receivers adopted by the Army, and Army Welfare broadcast receivers.

Volume 4 covers clandestine, agent or 'spy' radio equipment, sets which were used by special forces, partisans, resistance, 'stay behind' organisations, Australian Coast Watchers and the diplomatic service. Plus, selected associated power sources, RDF and intercept receivers, bugs and radar beacons.



ORDER YOURS TODAY!

JUST CALL 01202 880299 OR VISIT www.electronpublishing.com



433MHz Wireless Data Range Extender

There are many 'remote control' devices which rely on a 433MHz data link. You may have one and not even realise it – an alarm remote, a garage door/gate controller or even an outdoor weather station are just some examples. But is yours 100% reliable? Is the range a bit less than you'd like? Perhaps the remote unit is too far away from the receiver – or are there obstacles in the way?

Here's the answer: a small, solar-powered repeater placed between the transmitter and receiver with clear line-of-sight to both, giving you the reliability and extra range you need.

by John Clarke

There are quite a few devices which transmit periodic bursts of data on the 433MHz UHF 'LIPD' band, including a number of our designs, such as the *Driveway Monitor* (see July and August 2016 issues).

This includes some commercial devices too, such as remote weather stations. Unfortunately, it isn't always possible to get reliable reception.

Sometimes this is because there are hills, trees or buildings between the transmitter and receiver locations.

Other times, it's because of limited antenna sizes or the 25mW legal limit (10mW in the UK – see panel opposite) placed on unlicensed devices operating in this band (many 433MHz transmitters are far weaker than this). Even the weather can have an impact: a shrub or tree that has little to no effect in dry weather can play havoc with UHF signals in the wet.

While 433MHz signals aren't attenuated as much as higher frequencies (eg, 2.4GHz, which is also used for data), if you're suffering from marginal signal anyway, it could be enough to stop data getting through.

This *Repeater* can be placed in a location where it can clearly and reliably receive signals from the transmitter, and

which is also a better location for reception by the receiving unit (ie, placed in between the two devices).

It stores the received data and then, after a short delay, re-transmits the same signal in the same frequency band. So this design is suitable for extending the wireless range by up to two times, where line-of-sight transmission is possible. But it's also extremely effective at improving the signal integrity where the two units have obstructions between them, including buildings, trees and terrain.

Other things to try first

Before building a *Repeater*, there are some simple ways to improve range that may give you what you need. The first step is to try a better antenna.

Typically, our projects use a short length of wire as the antenna, sized to be one-quarter of the wavelength. This is around 170mm for a 433MHz transmitter or receiver.

Using a commercially made whip antenna for the transmitter and/or receiver can improve the range compared to the simple wire antenna, as can a longer half-wave antenna (340mm for 433MHz).

But we must caution you that if your transmitter is close to the 25mW legal limit (10mW, UK), using a better antenna (with higher gain) may be illegal. That's because 25mW (10mW, UK) is the effective radiated power limit, so it takes into account antenna gain. Each increase in antenna gain of 3dB is equivalent to doubling the output power.

So you cannot legally use a +3dBi antenna with devices that exceed 12.5mW (5mW, UK) transmit power.

Antenna orientation is important too. Having the transmitter and receiver antenna both with the same orientation, eg, both oriented vertically or both horizontally may improve range.

If these changes prove to be impractical or not effective enough, then it would make sense for you to build this *Repeater*. A *Repeater* is placed in the signal path between the transmitter and receiver.

In this case, the *Repeater* comprises a UHF receiver and UHF transmitter, plus a microcontroller, some memory and a power supply. Once the *Repeater* receives a valid signal, it

Features

- Extends the range of 433MHz transmitters
- Overcomes 'line-of-sight' limitations caused by trees and obstacles
- Receives 433MHz signal and re-transmits at 433MHz after a short delay
- Suitable for use with projects that transmit intermittent signal bursts
- Discrimination of genuine signal from noise
- Repeater chaining possible (with caution)
- Adjustable delay period
- Adjustable maximum data rate detection
- Solar power with LiFePO₄ cell storage
- Up to 200m open-space range with optimised antenna



With a solar panel to keep the internal battery charged, you'll never have to touch it once completed. Get up to double the range you had originally!

closer to both the transmitter and receiver than they are to each other, and possibly in a more advantageous location (eg, higher up) where there will be fewer obstacles in the way of both signal paths.

Other types of repeaters exist, which operate slightly differently to this one. For example, many repeaters retransmit the received signal on a different frequency.

That prevents conflicts between the transmitter and receiver and allows the repeater

is stored and then after a delay, retransmitted, to be received by the receiver.

This effectively increases the range for the transmission as it can be placed

to operate with effectively no delay. But the final receiver must be able to receive on the new frequency, so that type of repeater is not 'transparent'.

This *Repeater* retransmits in the same frequency band as the received signal. That means that the final receiver does not need to be modified in any way.

But the *Repeater* has to wait for the end of the transmission before resending. Otherwise, the received and transmitted signals will interfere, and the receiver could even go into a loop, continually retransmitting the same data.

Compatible projects

Some of the projects we have previously published that can benefit from using this *Repeater* include:

- *UHF Remote Switch* (January 2011)
- *Versatile 10-Channel Remote Control Receiver* (June 2014)
- *Driveway Monitor / Infrared to 433MHz UHF Transceiver* (July 2014).

All the projects mentioned above used the standard 433MHz UHF transmitters and receivers sold by Jaycar and Altronics (as shown overleaf).

Is this 433MHz repeater legal to use without a license?

Australia and New Zealand

In a word, yes. You can view the 'LIPD' class license for the 433MHz 'ISM' band, which applies to everyone in Australia, at: www.acma.gov.au/Industry/Spectrum/Radiocomms-licensing/Class-licences/lipd-class-licence-spectrum-acma

The equivalent New Zealand document is at: <https://gazette.govt.nz/notice/id/2017-go4089>

Note that the New Zealand EIRP limit of -16dBm is the same as the Australian limit of 25mW. It is simply specified in different units.

Neither of these documents place any restrictions on the use of the 433/434MHz LIPD band other than the maximum effective radiated power. There is nothing to limit how frequently you may transmit in that band, or how long the bursts can be. And there is no mention of repeaters whatsoever.

Since our repeater uses commercially available 433MHz transmitters, which comply with the power limit, and since it only transmits after the original transmission has ceased, it is entirely legal to operate in Australia and New Zealand.

However, we do not recommend that you use this repeater with any signals which transmit frequently. Typically, you would use it in conjunction with a device that sends a short burst (well under one second) no more frequently than, say, once every 30 seconds. If you used it with a device

transmitting rapidly, you could blanket the 433MHz band with transmissions in a 100-200m radius.

The Class License states that: 'If interference occurs, the onus is on the user of a LIPD to take measures to resolve that interference, for example by retuning or ceasing to operate the device.' (Retuning these devices would be difficult, if not impossible, without specialised equipment).

So keep that in mind, and use common sense when setting up your transmitting device and repeater(s).

In particular, stick to an aerial that is quarter wavelength – no longer.

It is the responsibility of the constructor to behave responsibly. Be aware of rules, don't break them.

From the PE editor

My thanks to a long-term reader and a *PE* columnist for providing advice for using this project in the UK.

United Kingdom

In the United Kingdom, LPD433 (<https://en.wikipedia.org/wiki/LPD433>) equipment that meets the respective Ofcom Interface Requirement can be used for model control, analogue/digitised voice, low-cost home automation and remote keyless entry systems. There is significant scope for interference however, both on frequency and on adjacent frequencies, as the band is widely used

Ofcom, together with the RSGB (Radio Society of Great Britain) Emerging Technology Co-ordination Committee

have produced guidelines to help mitigate the side effects of interference to an extent. (<http://bit.ly/pe-may20-ofcom1>).

UK power limitations

In *IR 2030 – UK Interface Requirements 2030* (<http://bit.ly/pe-may20-ofcom2>), Ofcom states (p.18) that applications must limit maximum power to 10mW, speech is not allowed and users must stick to a 10% duty cycle (ie, you must not hog the band, blocking other people's transmissions, you must be off the air for nine-times longer than you are on the air).

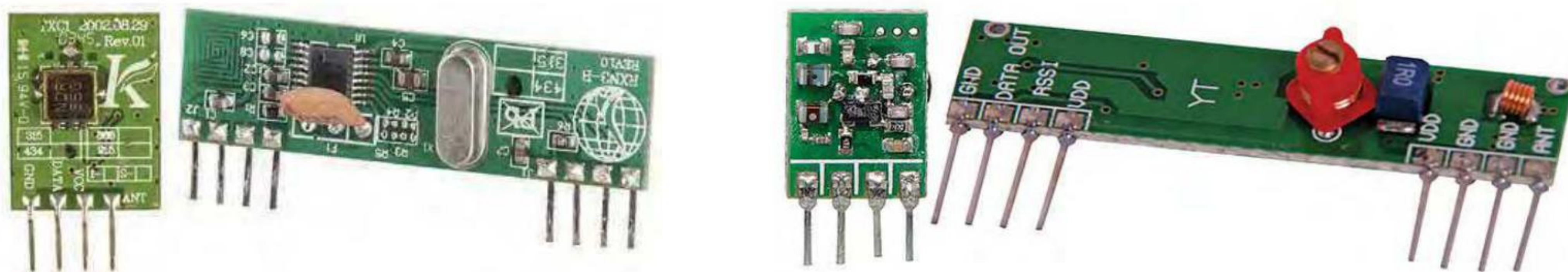
Do not make the common mistake of believing this is an unlicensed spectrum in the UK – there is no such thing. Bands like 433MHz are 'license exempt'. This means if you stick to the license published by Ofcom you don't need a specific licence, but there are still rules to follow.

Non-compliance is a criminal offence and Ofcom can (and do) prosecute (usually when something is interfering with some other user).

The RSGB outlines (<http://bit.ly/pe-may20-rsgb>) the modes in which radio amateurs can use 433MHz frequencies.

Bottom line

Used sensibly this project can be operated legally in the UK if you use legal modules. Also, do stick to the quarter-wave short antenna wires. (NB, linking repeaters in a chain might be considered unsportsmanlike and possibly illegal.)



The 433MHz *Data Repeater* is based on commercial transmitter and receiver modules, as shown here. The Jaycar ZW3100 transmitter and ZW3102 receiver are shown on the left with the Altronics Z6900 transmitter and Z6905 receiver at right. They are for all intents and purposes identical; either will fit directly into our PCB.

The Jaycar catalog codes are ZW3100 for the transmitter and ZW3102 for the receiver, while the Altronics catalogue codes are Z6900 for the transmitter and Z6905 for the receiver.

This *Repeater* may be able to be used with some other commercial devices transmitting data in the 433MHz band; however, whether it will work depends on the details of those transmissions, so it's hard to say that a particular device will or will not work until you try it.

Keep in mind that you need to use the *Repeater* in situations where it doesn't matter if the receiver could receive two identical packets in a short period.

That's because it may pick up both the direct transmission and the repeated transmission in some cases.

In all the projects mentioned above, this should not matter, as the receivers are effectively 'stateless'.

That should be true of many other devices such as weather stations. But again, you will need to try it out to confirm that the receiver's operation is not adversely affected by receiving multiple identical packets.

Presentation

Our *Repeater* is housed in an IP65 sealed box and that means it is suitable for use outdoors, in areas where it could be exposed to the weather.

It is designed to be powered from a solar panel and uses a single-cell LiFePO₄ rechargeable cell for power storage, so it can be used where there is no mains power available.

This is ideal, as you can, for example, mount it up on a pole, where it will have a good 'view' of both the transmitting and receiving units, and it should also get plenty of sunlight to keep the battery charged.

Circuit details

The circuit diagram of the *Repeater* is shown in Fig.1. It's based around microcontroller IC1, the previously mentioned 433MHz transmitter (TX1) and receiver (RX1), a 1024kbit/128kbyte static RAM (IC2), plus power supply parts such as the LiFePO₄ charger (IC3) and 5V step-up regulator (REG2).

Microcontroller IC1 monitors the signal from the UHF receiver (RX1), stores the received data in the SRAM (IC2) and then powers up the UHF transmitter (TX1) to send out the stored code that was previously received. IC1 also has two trimpots (VR1 and VR2) that are used to set the maximum data rate and the minimum retransmission delay; more on that later.

Receiver RX1 is powered continuously from the 5V supply so that it can receive a signal at any time. When

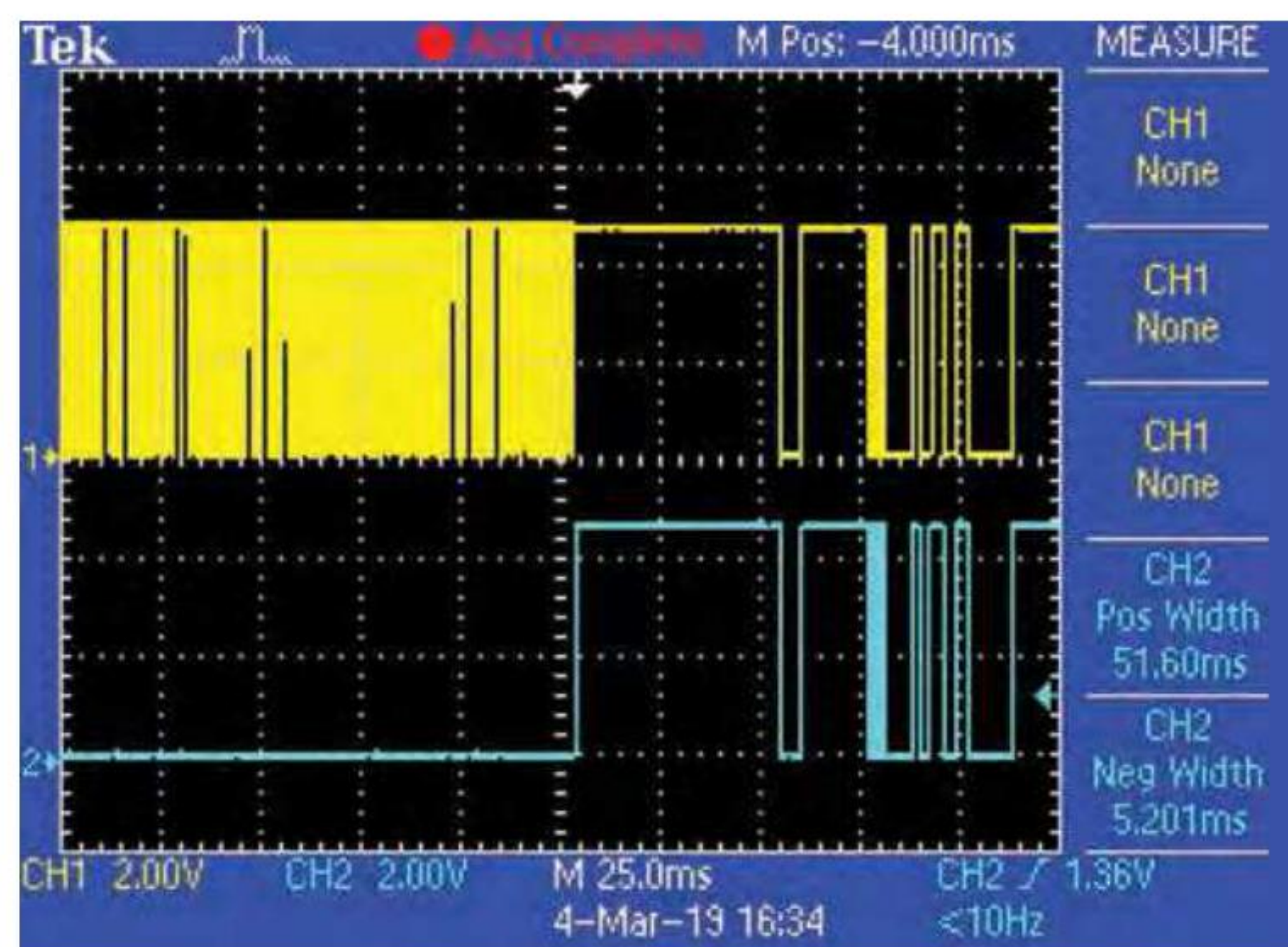
there is no signal to be received, its data output pin delivers a high-frequency random (noise) signal. That is due to the automatic gain control (AGC) in the receiver increasing gain until it is receiving a signal, even if that signal is just amplified noise.

When there is an actual 433MHz signal to receive, the AGC reduces the receiver's gain to prevent internal clipping, ie, so it is not overloaded due to excessive gain. Since the AGC gain varies at a relatively slow rate, when the 433MHz signal transmission stops, the receiver output will be low for a few hundred milliseconds before the AGC action increases the gain sufficiently to produce noise again.

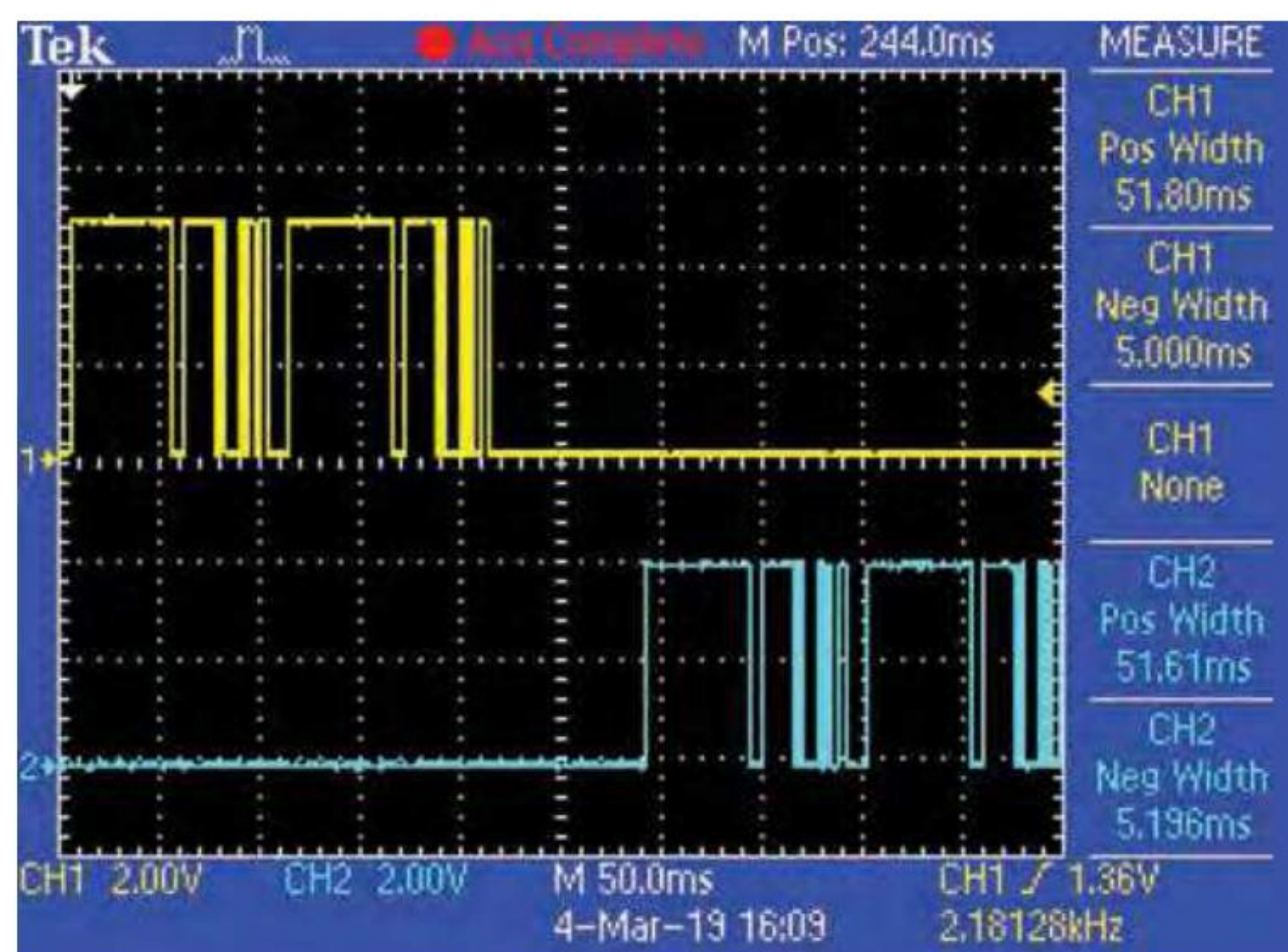
The 433MHz transmitter and receiver use an elementary modulation system, known as 'amplitude shift keying', or ASK. When its input is high (one), the transmitter produces a 433MHz carrier. When its input is low (zero), the 433MHz carrier transmission stops.

The data rate is usually fast enough that the receiver gain does not vary significantly during the burst, even though during the zero bits, there is no carrier.

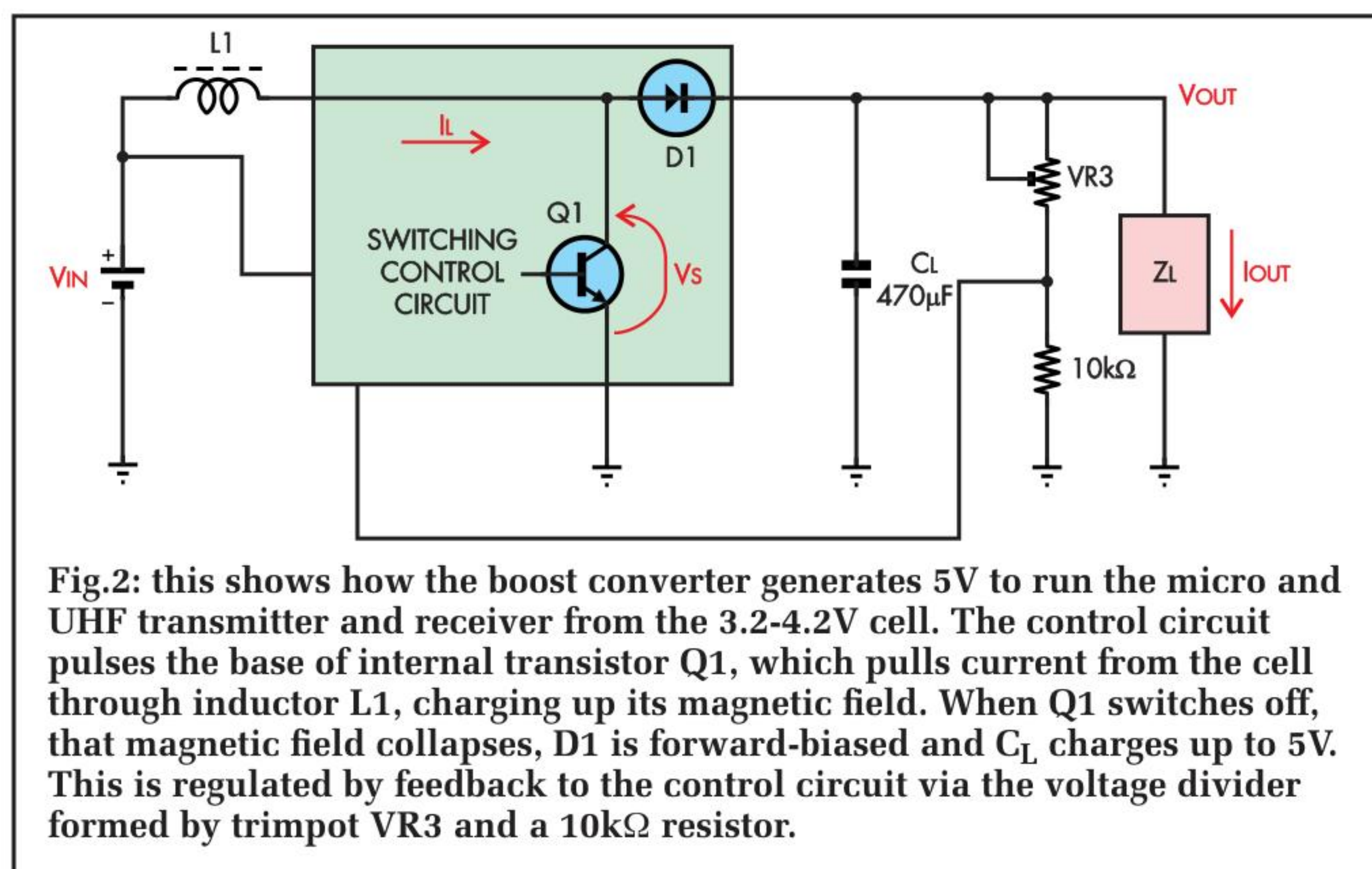
There are various schemes which exist to avoid having long periods of all 0s or all 1s, regardless of the data being transmitted, to help in cases like



Screen1: the yellow trace at the top is the output from the UHF receiver, RX1. You can see the high-frequency noise before valid data is received. When there is a received signal, the random signal ceases and the transmitted code is produced instead. IC1 rejects the noise and only accepts the valid code, as shown in the cyan trace below.



Screen2: the yellow trace at the top shows the original signal being received from the source, while the cyan trace at the bottom shows the signal being transmitted by the repeater. You can see how it does not start transmission until it has finished receiving an entire packet, and there is a short delay before retransmission, around 60ms in this case.



The circuit is powered from a single 600mAH LiFePO₄ cell. The quiescent current draw is around 9.4mA (when the transmitter, memory and LEDs are off). This means the cell will last for around 60 hours or 2.5 days when fully charged.

Charging circuitry

The LiFePO₄ cell is charged by IC3, which is powered from a 5V regulator (REG1) and this, in turn, is powered from a solar panel. Note that it connects to the circuit via a fuse (F1), which prevents damage if the cell is inserted incorrectly. If the cell is reversed, current will flow through diode D2 and blow the fuse. Diode D1 prevents damage if the solar panel is accidentally connected with the wrong polarity.

IC3 is a miniature single-cell integrated Li-ion/LiPo charge management controller. It charges the cell at a constant current, up to a charge termination voltage of 4.2V. The charge current is set by the resistance at pin 5, and for our circuit, this is set to 100mA by the 10kΩ resistor. The charge LED (LED3) lights when the cell is charging.

The 433MHz UHF transmitter (TX1) and receiver (RX1) can operate from 2.5-5V. Since the transmitter will have more output power and thus a better range when powered from 5V, rather than the 3.2-4.2V from the LiFePO₄ cell, we use a step-up (boost) regulator to generate 5V to power these modules.

However, the circuit can be built without this step-up regulator, if maximum range is not required. This saves time and money. The rest of the circuit will then be powered directly from the LiFePO₄ cell. This would also extend the cell life as the step-up regulator is only around 70% efficient, and the lower supply voltage will also mean that less current is drawn by IC1, IC2, TX1 and RX1.

Jumper link JP2 is used to select whether these components are powered from the 5V boosted supply, or directly from the cell.

The voltage step-up is performed by TL499A switching regulator REG2. It comprises a switching control circuit, a transistor and a series diode. It requires inductor L1 to perform the boost function and a 470μF low-ESR output capacitor for energy storage and filtering.

A simplified circuit showing the operation of the boost converter is shown in Fig.2. Initially, internal transistor Q1 is on and current flow begins to build through inductor L1 (at a rate limited by its inductance) until it reaches a particular value. This maximum current is set by the resistor connected to pin 4 of REG2.

When Q1 switches off, L1's magnetic field collapses and so current continues

RA4 (pin 3) of IC1 at the same rate that it was received. At the same time, TX1, the UHF transmitter is powered up and transmits this stored data (see Screen2).

IC2 is the memory that is used to store the data. It is a 1024kbit random access memory organised as 128k × 8-bit bytes. The memory is read and written via a Serial Peripheral Interface (SPI).

When writing, data is sent to the SI input of IC2 (pin 5) from the SDO (pin 8) output of IC1, one byte at a time. When reading, data is sent from the SO output of IC2 (pin 2) to the SDI input (pin 7) of IC1; again, one byte at a time. In both cases, the data is clocked by a signal from the SCK (pin 10) of IC1, which is fed to the SCK input of IC2 (pin 6).

The memory SPI interface is enabled by a low level at the chip select ($\overline{CS}$) input (pin 1) of IC2, which is driven from the RB3 digital output of IC1 (pin 9).

To write to the memory, the $\overline{CS}$ line is brought low and then a write instruction is sent from IC1 to IC2, followed by the memory address to write to. In our application, this is always the first location (address zero). This is a 24-bit address sent as three 8-bit bytes. The seven most-significant address bits are always zero since only 17 bits are required to address the 128k bytes in the RAM.

Following this, data can be written, one byte at a time. By default, the address is automatically incremented after each byte of data is written, so bytes are written sequentially to the RAM.

We store the received data as 16-bit values. The most-significant bit (bit 15) indicates the received level, low (0) or high (1). The remaining 15 bits are used to store the duration that the data stayed at that level. This period is stored in increments of 4μs, resulting in a 4μs minimum period and 131ms maximum.

Reading data out of the memory is a similar process to writing, except that a different instruction is used and the

data is sent in the opposite direction, from IC2 to IC1.

Power saving features

Since we are powering the *Repeater* using solar panels and a small cell for storage, its power consumption must be minimised, especially when idle and waiting for data. This is done by switching off power to components when they are not required.

The two trimpots, VR1 and VR2, are only connected to the 5V supply when their positions are being read. This is done only during the initial power-up process and when switch S1 is pressed. Any other time, the RA6 and RA7 pins that supply 5V to the trimpots are low (0V), to prevent current flow through the pots. This saves 1mA, which adds up to 24mAh per day.

Similarly, the transmitter (TX1) is off until it is required to send a UHF signal. TX1 is powered directly from IC1's RA2 and RA3 digital outputs (pins 1 and 2); these go high (to 5V) to power TX1. The power saving is considerable since TX1 draws some 10mA when powered and transmitting. This saves 240mAh/day.

IC2 is on standby unless it is being used. So unless there is a valid data being received, it draws just 10μA instead of the 10mA required when it is active. Typically, the memory is only powered twice as long as the transmitter; the first half being the reception period and the second half being the transmission period. This also saves around 240mAh/day.

Microcontroller IC1 typically draws 1.7mA and UHF receiver RX1 draws 2.9mA. The transmit and receive LEDs are powered when TX1 and RX1 are active respectively, and draw about 3mA. The LEDs can be disconnected using a jumper shunt (JP1) to save power if they are not needed. They are mainly provided for testing purposes.

to flow to the load and output capacitor (C_L) via diode D1. This current flow causes a voltage to appear across L1, which adds to the supply voltage (V_{IN}), charging C_L up to a higher voltage than the input supply.

The process continues with Q1 switching on again, once L1's magnetic field has mostly dissipated, and thus the field builds back up until Q1 switches off again.

The output voltage is sampled via a voltage divider comprising trimpot VR3 and a 10k Ω resistor. This determines the proportion of the output voltage applied to pin 2 of REG2, which it compares against an internal 1.26V reference. The duty cycle of Q1 is controlled to maintain 1.26V at the pin 2 input.

Therefore, by changing the resistance of VR3, we can vary the output voltage. The greater the attenuation of this resistive divider, the higher the output voltage must be to maintain 1.26V at pin 2. If VR3 is set to 29.68k Ω , the divider formed with the 10k Ω resistor reduces the output by a factor of 3.97. That means that the output will be $3.97 \times 1.26V = 5V$.

Should the output voltage rise slightly above 5V, the TL499A will cease switching Q1 until the voltage falls slightly below the 5V level. Should the voltage fall below 5V, the transistor will be driven with a higher duty cycle, to deliver more current to the output and bring it back up to 5V.

Note that the 1.26V reference is only a nominal value and could be any voltage between 1.20V to 1.32V, depending on the particular IC. So VR3 makes it adjustable, to allow the output voltage to be set accurately.

Chaining multiple repeaters

As mentioned in the features panel, it is possible to have more than one *Repeater*, to extend the transmission range further – this is not recommended for UK operation unless you know what you are doing and how to avoid interfering with neighbouring signals. The *Repeater* closest to the source (original transmitter) will send the signal on to the second *Repeater*. When the second *Repeater* sends out its signal, the first *Repeater* must ignore it; otherwise the two *Repeaters* will endlessly retransmit the same packet.

This is prevented by an adjustable delay between the end of each transmission and the unit accepting a new packet. This delay ranges from 50ms to 12.5s and is set using VR2. The voltage at TP2 indicates the delay setting, with each volt representing 2.5s. So for example, if VR2 is adjusted for 2V at TP2 then the delay is $2.5s \times 2 = 5s$. 0V gives a 50ms (minimum) delay.

Construction

The *Repeater* is built using a double-sided PCB coded 15004191, which measures 103.5 x 78mm and is available from the *PE PCB Service*. It fits in an IP65 sealed box measuring 115 x 90 x 55mm. Use the PCB overlay diagram, shown in Fig.3, as a guide during assembly.

Start by soldering the battery charger, IC3. This is in a small five-pin SMD package. The correct orientation is evident since it has two pins on one side and three on the other. Tack solder one of the pins (ideally, at upper right) then check its orientation and solder the diagonally opposite pin.

Then proceed to solder the remaining pins, and refresh the first joint with a bit of added solder or flux gel.

If you accidentally bridge the three pins which are close together, add a little flux paste and then clean up the bridge with the application of some solder wick.

The PCB has the option to use a DIP (through-hole) or SOIC (SMD) package for the memory chip (IC2). Only one type should be installed. If using the SOIC package, solder it next, using a similar procedure as described above. But first, make sure that its pin 1 dot or divot is at upper left, as shown in Fig.3. It should also have a bevelled edge on the pin 1 side.

Parts list – 433MHz Wireless Data Repeater

- 1 double-sided PCB coded 15004191, 103.5 x 78mm, available from the PE PCB Service
- 1 IP65 enclosure, 115 x 90 x 55mm [Jaycar HB6216]
- 1 600mAh LiFePO₄ cell (AA sized: 50mm diameter, 14mm long) [Jaycar SB2305]
- 1 12V 5W solar panel [Jaycar ZM9050]
- 1 panel label (see text)
- 1 15 x 8 x 6.5mm powdered iron toroid (L1) [Jaycar LO1242]
- 1 433MHz ASK transmitter (TX1) [Altronics Z6900, Jaycar ZW3100]
- 1 433MHz ASK receiver (RX1) [Altronics Z6905, Jaycar ZW3102]
- 1 PCB-mount tactile momentary SPST pushbutton switch (S1) [Altronics S1120, Jaycar SP0600]
- 1 2-way screw terminal with 5.08mm spacing (CON1)
- 1 2-pin header, 2.54mm spacing (JP1)
- 1 3-pin header, 2.54mm spacing (JP2)
- 2 shorting blocks/jumper shunts (JP1,JP2)
- 1 1A M205 fuse (F1)
- 2 PCB-mount M205 fuse clips (F1)
- 1 18-pin DIL IC socket (for IC1)
- 1-2 8-pin DIL IC sockets (optional; for IC2 and REG2)
- 1 PCB-mount AA cell holder
- 1 flag heatsink, 19 x 19 x 9.5mm [Altronics H0630, Jaycar HH8502]
- 1 IP65 cable gland to suit 3-6.5mm diameter cable
- 6 PC stakes (optional)
- 4 M3 x 5mm panhead machine screws
- 1 M3 x 6mm panhead machine screw
- 1 M3 hex nut
- 2 4.75mm long #0 panhead self-tapping screws
- 2 100mm cable ties
- 1 500mm length of 1mm diameter enamelled copper wire
- 2 175mm lengths of medium-duty hookup wire **OR**
- 2 175mm length of 1mm diameter enamelled copper wire (see text)

Semiconductors

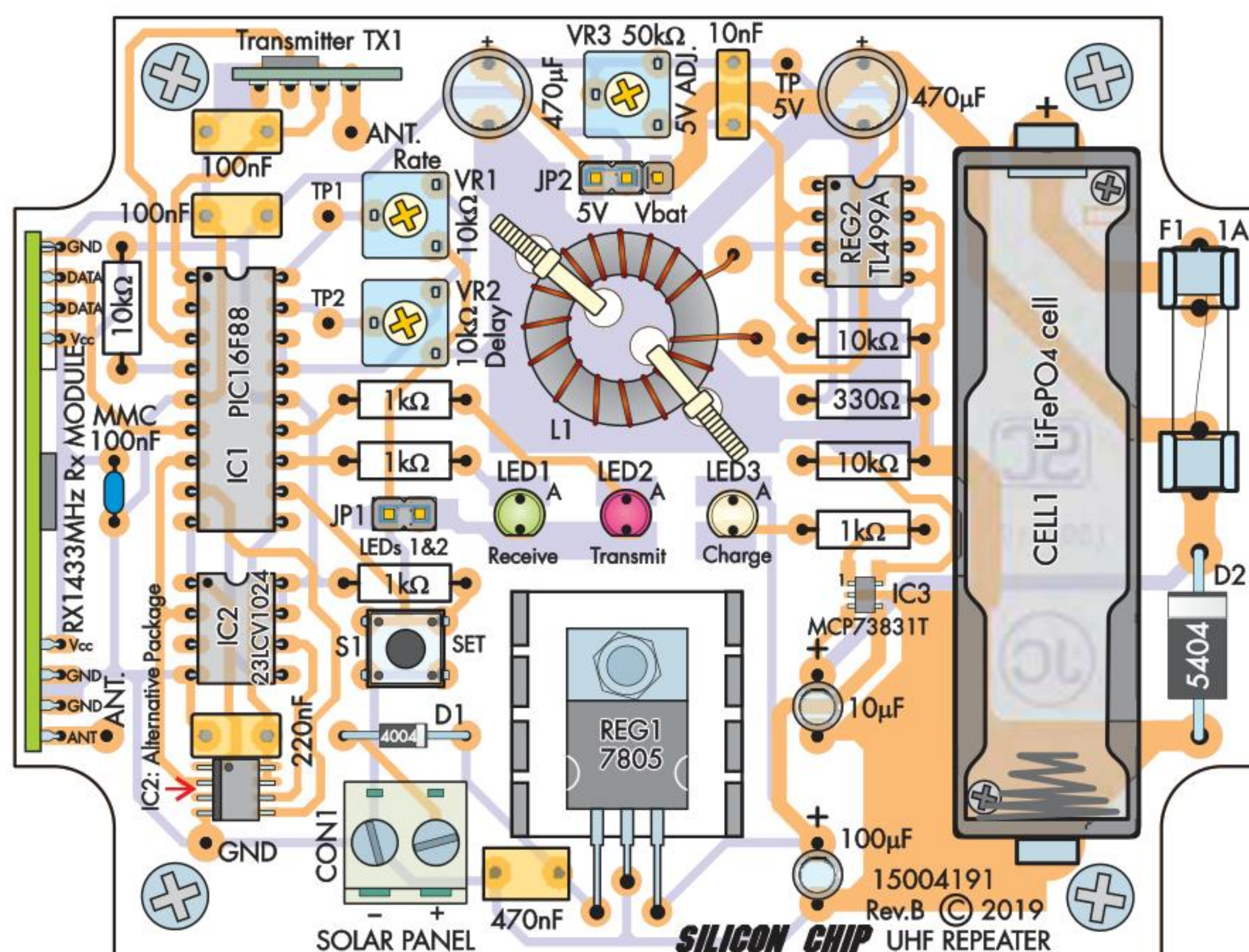
- 1 PIC16F88-I/P 8-bit microcontroller programmed with 1500419A.HEX (IC1)
- 1 23LCV1024-I/P 128kB SRAM in PDIP package (IC2) [Mouser, Digi-Key] **OR**
- 1 23LCV1024-I/SN 128kB SRAM in SOIC package (IC2) [Mouser, Digi-Key]
- 1 MCP73831T-2ACI/OT single cell Li-ion/LiFePO₄ charger, SOT-23-5 (IC3) [Mouser, Digi-Key]
- 1 TL499A power supply controller (REG2) [Jaycar Cat ZV1644]
- 1 7805 5V regulator (REG1)
- 1 1N4004 1A diode (D1)
- 1 1N5404 3A diode (D2)
- 1 Green 3mm high-brightness LED (LED1)
- 1 Red 3mm high-brightness LED (LED2)
- 1 Yellow 3mm high-brightness LED (LED3)

Capacitors

- 2 470 μ F 16V low-ESR electrolytic
- 1 100 μ F 16V electrolytic
- 1 10 μ F 16V electrolytic
- 1 470nF 63V MKT polyester (code 0.47, 474 or 470n)
- 1 220nF 63V MKT polyester (code 0.22, 224 or 220n)
- 2 100nF 63V MKT polyester (code 0.1, 104 or 100n)
- 1 100nF multi-layer ceramic
- 1 10nF 63V MKT polyester (code 0.01, 103 or 10n)

Resistors (all 0.25W, 1% metal film)

- 3 10k Ω 4 1k Ω 1 330 Ω
- 2 10k Ω miniature horizontal mount trimpots (VR1,VR2)
- 1 50k Ω miniature horizontal mount trimpot (VR3)



The SOIC package for IC2 is larger than that of IC3, so you should find it a little easier. Again, any accidental bridges can be cleaned up with flux paste and solder wick.

Install the resistors next. A digital multimeter should be used to check the resistor values, as the colour codes can be hard to read.

Fit the diodes next, making sure to insert them with the correct polarity, ie, with the striped ends facing as shown in the overlay diagram. D2 is considerably larger than D1.

We recommend soldering an IC socket for IC1. The remaining ICs (including IC2, if using the DIP package version) can be fitted via an IC socket or soldered directly in place, which would give better long-term reliability.

Take care with orientation when installing the socket(s) and ICs. Additionally, make sure that IC2 and REG2 are not mixed up.

Next, there are six optional PC stakes to install, which make wiring connections and test point monitoring easier. These are located at TP5V, GND, TP1, TP2 and one each for the antenna connection of RX1 and TX1.

The capacitors should be mounted next, starting with the 100nF multi layer ceramic capacitor next to UHF receiver RX1, then following with the MKT polyester types, none of which are polarised. Follow these with the electrolytic types, which must be installed with the polarity shown; the longer lead goes into the pads marked with a '+' sign, towards the top of the PCB.

REG1 can be now fitted. It is mounted horizontally on a heatsink. Bend the leads so they fit the PCB holes while the mounting hole lines up with the hole on the PCB. Sandwich the heatsink between the regulator and PCB and do up the screw and nut before soldering the leads.

Trimpots VR1 to VR3 are next. VR1 and VR2 are 10k Ω and would typically be marked with 103. VR3 is 50k Ω and may be marked as 503. Then install the LEDs, LED1 to LED3. In each case, the anode (longer lead) goes to the pad marked with an 'A' on the PCB. The bottom of the LEDs should be about 5mm above the PCB surface when soldered in place. You can then fit pushbutton switch S1.

Install the 3-way and 2-way SIL headers now, for JP1 and JP2. Then fit the 2-way screw terminal, CON1, with the wire entry holes end toward the bottom PCB edge.

L1 is wound using 17 turns of 1mm enamelled copper wire on a 25mm-diameter powdered iron toroidal core. These turns should be wound neatly around the perimeter, as shown in Fig.3. Remove the enamel from the ends of the wires using a hobby knife so you can tin them and then solder them to the PCB pads shown. The core is held in place with two cable ties that loop through PCB holes, as shown.

The battery holder must be oriented as shown (red wire to +) and secured to the PCB using two self-tapping screws through the cell holder and into the slotted holes on the PCB. Cut the wires from the battery short and terminate them to the PCB.

Insert the fuse clips for F1, making sure that the end stops in the clips are facing to the outside. Before soldering them, insert the fuse so that the clips are correctly aligned, for good contact with the fuse.

Finally, the UHF transmitter and receiver can be mounted. These must also be oriented correctly. The pin markings are printed on the transmitter module. Orient the antenna pin connection on the transmitter and receiver so that they are adjacent to the antenna connections on the PCB.

You have two options for the antennas: either use 170mm lengths of hookup wire coiled inside the box or, for better range (>40m), 170mm-long lengths of stiff enamelled copper wire protruding from the box.

The extra 5mm in the lengths specified in the parts list is to give you enough wire to solder to the antenna terminals (for the hookup wire) or to bend over at the tip (for the enamelled copper wire).

Having chosen which antenna wire you want to use, cut the appropriate lengths and solder them to the antenna PC stakes, or directly to the antenna pads if you are not using PC stakes.

Note that you will need to scrape some insulation off the end of the enamelled copper wire (eg, with a hobby knife) so that you can tin and then solder it to the board.

Mounting it in the box

There is not much work required to mount the board in the box. We drilled a hole in the side for the cable gland required for the solar panel wiring.

This hole is 25mm up from the outside base of the case opposite CON1. If you only require a UHF transmission range of less than 40m, the antenna wires can be bent around the inside perimeter of the box.

For maximum transmission range (up to 200m), the stiff receiver antenna wire should pass through a small hole in the upper edge of the box, and the receiver wire similarly should pass through a small hole in the lower edge of the box.

Once it's through, bend the tips over to form small 3mm loops. That prevents you poking your eye out on the other-wise sharp end.

1mm wire is used so that the wire is stiff enough to stay straight. The wire exit holes should then be sealed with a neutral cure silicone sealant.

The *Repeater* PCB is held inside the case by M3 screws that go into the integral threaded bushes in the base of the box.

The Neoprene seal for the lid needs to be placed inside the surround channel and then cut to size. The start and finish gap in this seal should be along the lower long edge of the lid.

Labelling it

To produce a front-panel label, you have several options. For a rugged label, mirror the design and print it onto clear overhead projector film (using film suitable for your type of printer). This way, the ink will be on the back of the film when the label is affixed. Attach with clear silicone sealant.

Solar panel or mains power

We used a 12V 5W solar panel to power the unit. A 6V panel would be more efficient, since we are reducing the voltage down to 5V. However, 6V panels aren't easy to find. The panel power rating only needs to be 1W.

If you want to run the unit from mains power, a 9V plugpack could be connected to CON1 instead.

Make sure the plugpack is out of the weather, with only the low voltage wires going to the *Repeater*.

In this case, IC3 and the LiFePO₄ cell are not required, although you could leave them in so that the unit will run even during power outages (assuming the transmitting and receiving units are also battery-powered).

If you're leaving off IC3, you could also omit F1, D2, LED3 as well as IC4 and its associated parts. The 5V output from REG1 could then be directly used to power the circuit by connecting a wire link from the regulator output to the 5V terminal at JP2.

Setting up

It is essential that the shunt is not placed on JP2 until VR3 is adjusted for 5V at the output of IC4. To do this, insert the LiFePO₄ cell into the holder and measure the voltage between the GND and TP5V PC stakes. Adjust VR2 for a reading of 5V.

Reproduced by arrangement with
SILICON CHIP magazine 2020.
www.siliconchip.com.au

Installation

The *Repeater* should be mounted in a location that will give good reception of the original UHF signal. The LED indicators (LED1, LED2) will let you know if the signal is received and retransmitted if a shunt is installed on JP1.

VR1 must be adjusted so that the receive LED does not flash at all, or at least not too often, when no signal is being received. But if it's adjusted too far, the *Repeater* will not work, so you need to check that it is still retransmitting valid data.

To achieve this, initially set VR1 fully clockwise and press S1 so that the VR1 setting is updated. More of the random signal noise will now be detected and the receive LED will flash now and then, followed by the transmit LED. Adjust VR1 anticlockwise a few degrees and press S1 to again update the setting. Check that the *Repeater* retransmits correctly.

If the *Repeater* operates correctly, try further anticlockwise adjustment. The final adjustment will be a compromise between reliable *Repeater* operation and noise rejection from the UHF receiver. Adjusting VR1 too far anticlockwise will prevent successful *Repeater* operation.

VR2 should be set fully anticlockwise if you are using a single *Repeater*. If you are using multiple *Repeaters*, set VR2 on all *Repeaters* fully clockwise, giving a 12.5s delay. If your transmitter can send signals more often than this, you will need to experiment with the maximum clockwise rotation of VR2 that will still cause all valid packets to be relayed.

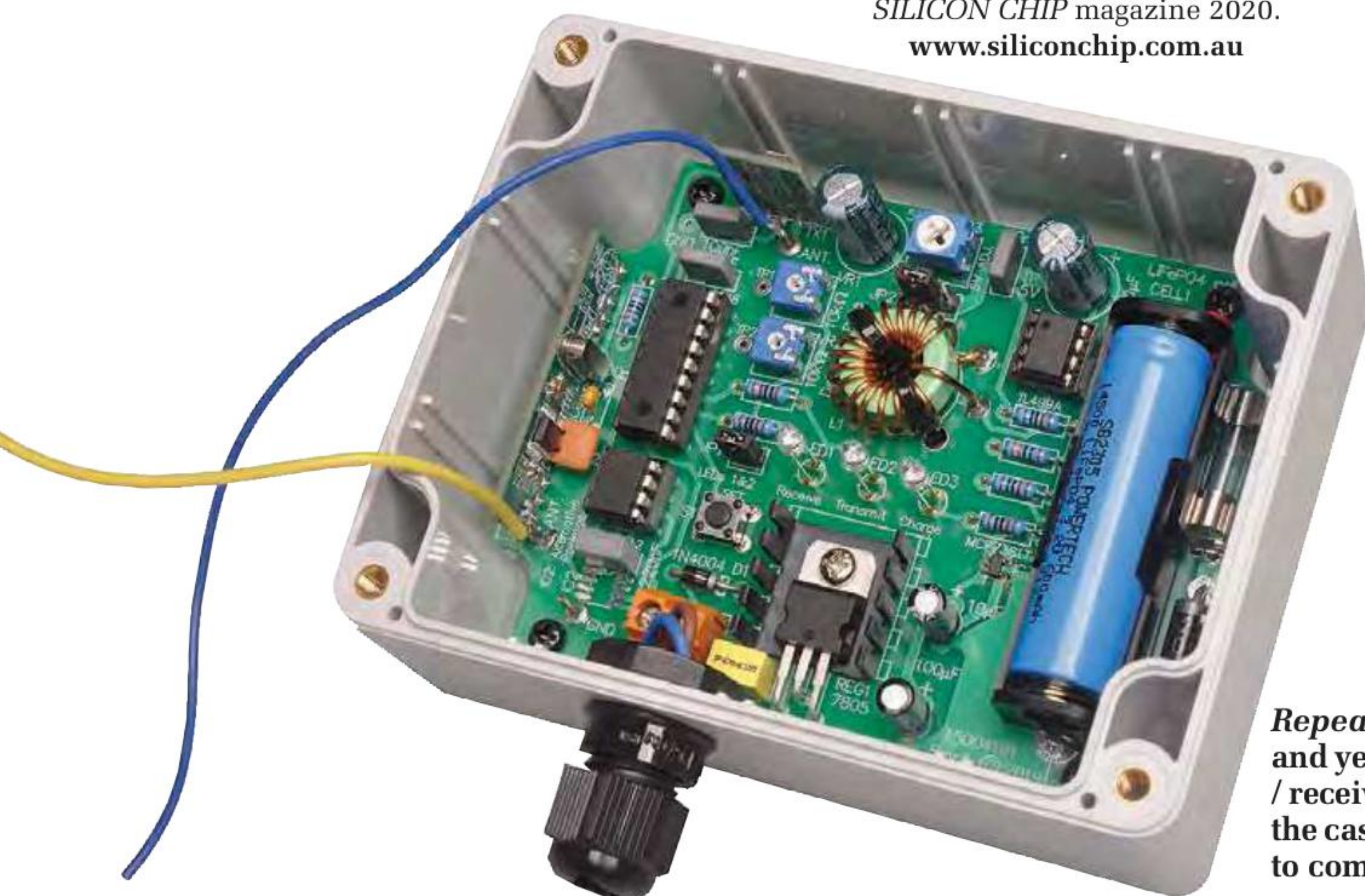
Remember that the settings for the VR1 and VR2 trimpots are only read by IC1 when first powered up and when S1 is pressed. LED1 and LED2 light when S1 is pressed, to acknowledge that the settings have been updated.

Once you've finished adjusting VR1 and VR2, you will need to check whether the ultimate receiver is correctly decoding the retransmitted code from the *Repeater(s)*. If not, you may need to move them.

You can then permanently mount the *Repeater(s)*. This is done using the mounting holes provided in the box corners. These holes are accessible when the box lid is removed.

Alternatively, you could use a bracket and attached it to the box using the box mounting holes. Avoid drilling extra holes in the box as this could compromise its water-tight seal.

***Repeater* mounted in its waterproof case. The blue and yellow wires are the 170mm-long transmitting / receiving antennas – they can be left 'floating' in the case, but ensure there are no bare ends to short to components or the PCB.**



Need Extreme, Earth-shattering Power?

Want to unlock immense power from an audio amplifier and speaker? You can combine this easy-to-build unit with a standard stereo amplifier to easily get 400W into a single 8Ω speaker. That's about three times the power that amp would typically manage. With the right amplifier, you could even get 1000W or more – per channel!

Bridge-mode Audio Amplifier Adaptor

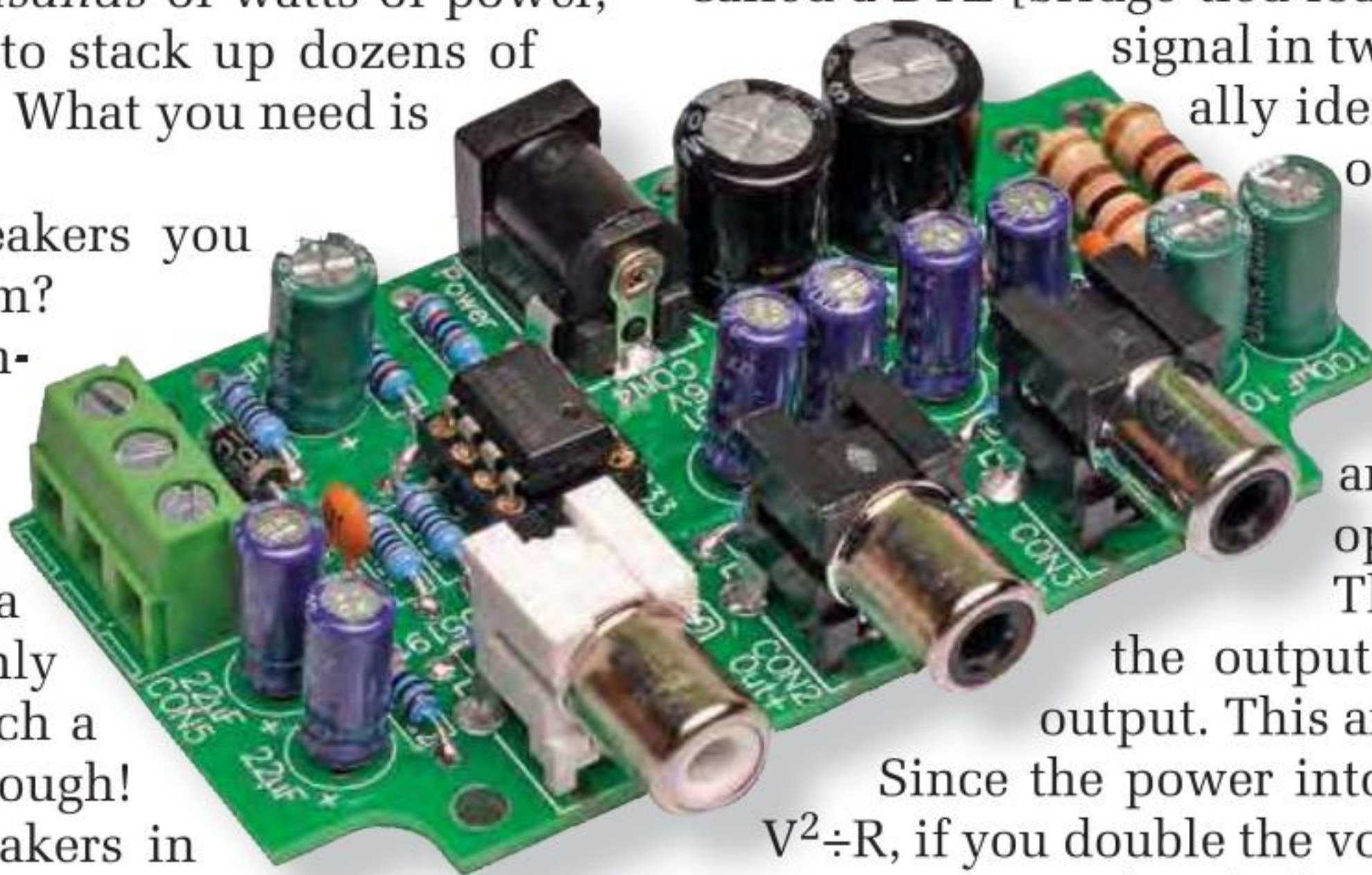
Let's say you want to put on a rock concert. You're going to need *thousands* of watts of power, and it's a bit impractical to stack up dozens of smaller amplifiers and speakers. What you need is something B I G !

Assuming you have the speakers you need, how would you drive them?

Many potent audio power amplifiers produce their full-rated power output into a 4Ω load. But all too often speakers have an 8Ω impedance, and so, for example, a 500W amplifier module would only achieve a measly 278W into such a load; and that's just not good enough!

The trick is to drive the speakers in bridge mode. If you use two amplifiers, plus this little device, you can drive a single 8Ω speaker with two amplifiers, and achieve full amplifier power.

Thus, because the speaker's impedance is effectively halved when being driven in bridge mode, you will get that 500W figure from each amp: 500W + 500W = 1kW. Rock on!



The way it works is simple. This *Bridge Adaptor* (often called a BTL [bridge-tied load] adaptor) splits your audio signal in two. One output signal is virtually identical to the input, while the other is inverted.

So when you connect those outputs to two audio amplifiers (possibly the two channels within a single stereo amplifier), the outputs swing in opposite directions.

That means the voltage between the outputs is double that of a single output. This arrangement is shown in Fig.1.

Since the power into a load can be calculated as $V^2 \div R$, if you double the voltage but keep the impedance constant, you quadruple the power.

Of course, this is assuming your amplifier is capable of delivering that much power. But if you use an 8Ω speaker, since most amplifiers will happily drive a 4Ω load, it should be capable of it. (You must be careful if using a 6Ω or 4Ω speaker; many amplifiers aren't very happy with a 3Ω or 2Ω effective load.)

BY NICHOLAS VINEN

Performance

We ran our prototype through a number of tests using our Audio Precision System Two. We haven't reproduced any of the resulting graphs here since the results can be summarised in just a couple of paragraphs. We used a 15V AC plugpack as the power source during these tests.

The distortion and noise levels are very low. The signal-to-noise ratio is 114dB with respect to 2V RMS (a common signal level from a CD/DVD/Blu-ray player), with a measurement bandwidth of 20Hz-22kHz. The frequency response is ruler-flat, being only 0.2dB down at 20Hz and less than 0.1dB down at 20kHz.

THD+N is 0.0005% from the non-inverting output and 0.0006% from the inverting output over the 20Hz-20kHz range with an 80kHz bandwidth.

Measuring with a 20kHz bandwidth, these figures reduce to 0.0003% and 0.0005% respectively. The distortion across the two outputs (ie, what you would actually hear) measures the same as the inverting output.

Updated version

We published a *Bridge Adaptor* in the October 2010 issue. This one is considerably smaller and will fit into a UB5 Jiffy box for convenience. But you also have the option of building it into an amplifier chassis if that's what you want.

This design also has much more flexible power supply options. It will run off AC, DC or split rails. It also uses parts that are easier to get, and cheaper, than our last design.

The circuit diagram is shown in Fig.2. The input audio signal is fed in via RCA socket CON1, which has a 100k Ω resistor to bias the input signal to 0V (if it's floating). That signal then passes through two 'back-to-back' electrolytic capacitors.

We've used this arrangement, rather than a single non-polarised (NP) electrolytic capacitor because the size and cost of NP capacitors can vary dramatically. By using two small, low-cost regular electrolytics, we get the same effect with a low price and small footprint.

The signal is DC-biased to signal ground (more on that later) with a 10k Ω resistor, and RF signals are filtered out by a 100pF ceramic capacitor. The signal is then applied to the non-inverting input, pin 3, of low-noise op amp IC1a.

IC1a acts as a buffer, feeding both non-inverted RCA output connector CON2, and the inverting stage, which is based around op amp IC1b. The signal to CON2 passes through another pair of 22 μ F DC-blocking capacitors and is re-biased to 0V DC via a 100k Ω resistor.

The 100 Ω series resistor protects IC1a against an output short circuit and also isolates any cable capacitance to prevent oscillation.

Features and specifications

- Up to four times the power into a single speaker, using a stereo amplifier or two mono amplifiers
- Low noise and distortion
- Powered from 9-16V AC, 12-40V DC, 18-32V centre-tapped transformer or $\pm$ 6-20V DC (split rails)
- Low current draw – around 10mA
- Fits inside a compact, low-cost UB5 Jiffy box
- Can also be mounted inside an amplifier chassis
- A switch can be used to change amp mode between stereo and bridged mono
- Uses low-cost, commonly available parts
- Suitable project for beginners

IC1b is configured as a classic inverter with a gain of -1, set by the ratio of the two 2k Ω resistors. These values were chosen to keep noise to a minimum without unduly loading the output of IC1b.

After all, it has to drive whatever is connected to inverting RCA output connector CON3 as well. The signal is coupled from IC1b to CON3 in the same manner as described for CON2 above.

IC1b's non-inverting input, pin 5, is tied to signal ground via a 1k Ω resistor. This means both of its inputs (pins 5 and 6) have the same source impedance, as the two 2k Ω resistors which are effectively in parallel, given that both are driven from op amp outputs, which have an effective impedance close to 0 Ω .

Power supply options

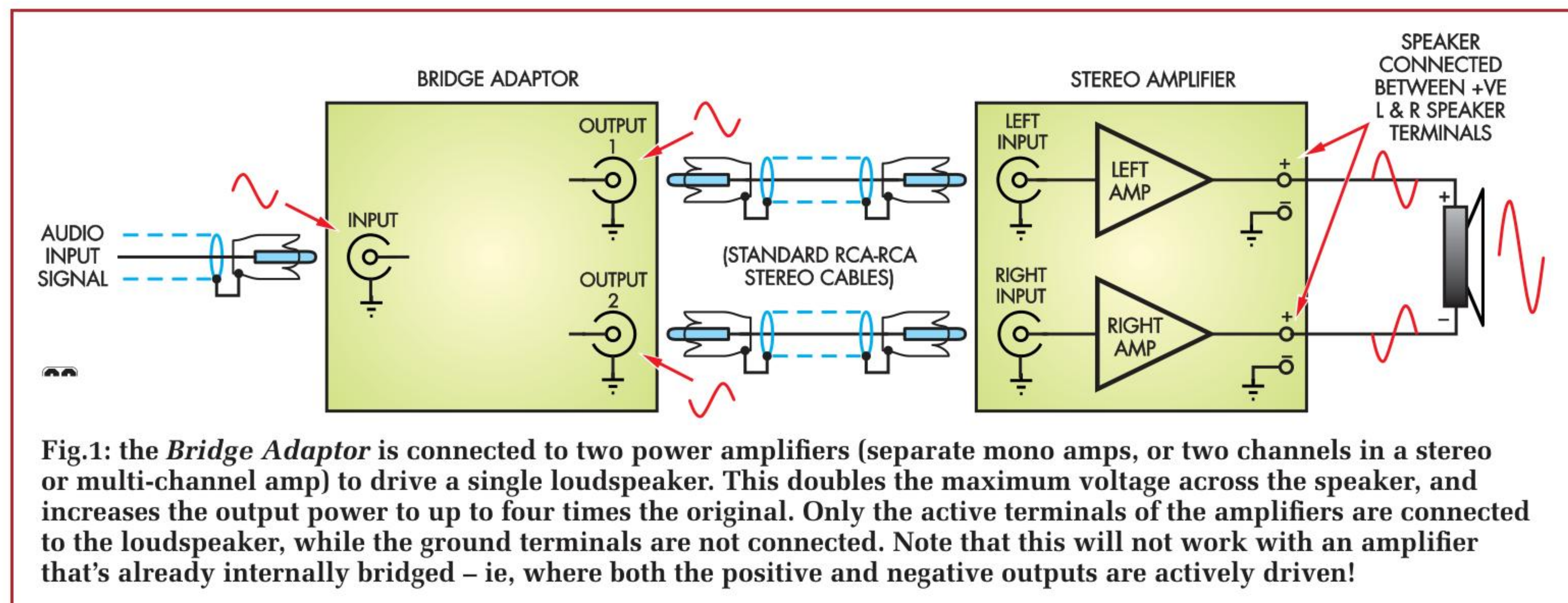
You can power the *Bridge Adaptor* from a 9-16V transformer, standalone or plugpack, or you can use a 12-40V DC supply, a $\pm$ 6-20V DC split supply, or an 18-32V centre-tapped transformer.

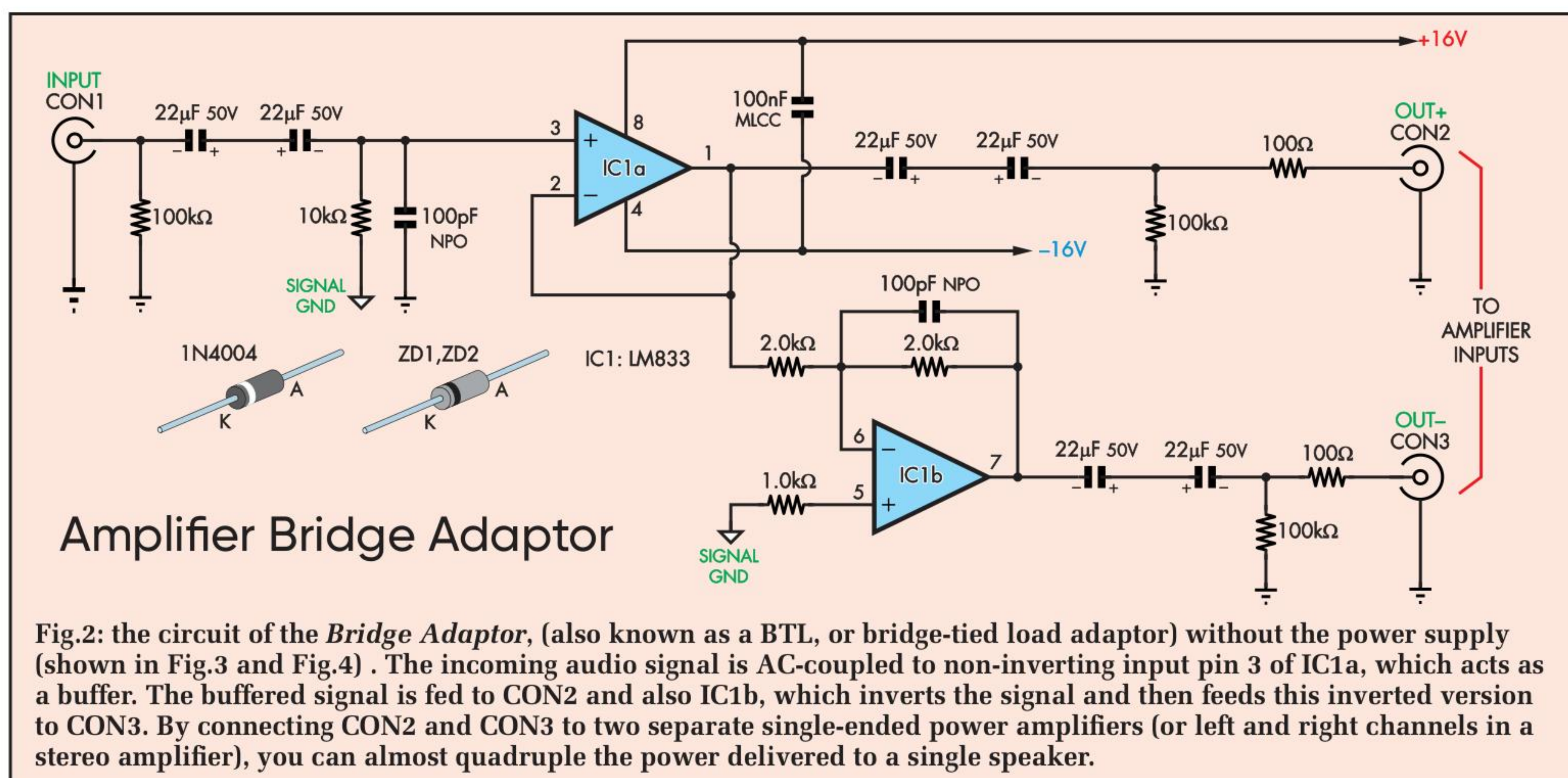
That last option is most useful if you're building this project into an amplifier chassis. Later on, we'll show you how to wire up a switch so that an amplifier can be easily configured as either stereo or bridged mono.

When the unit is powered from AC or a split rail DC supply, signal ground is tied to power supply ground by a 0 Ω resistor (ie, wire link), as shown in Fig.3.

But if the unit is powered from a single DC supply (eg, 12V DC) then signal ground needs to be around 6V DC, so that the AC signals have a symmetrical swing.

The power supply section is therefore reconfigured, as shown in Fig.4, by omitting some components and replacing others with wire links.





In this case, the 0Ω resistor is instead $10k\Omega$, and another $10k\Omega$ resistor forms a voltage divider across the DC supply rail, to generate a half-supply rail for signal ground. A $220\mu F$ capacitor between signal ground and power supply ground prevents any ripple or noise on the supply rail from getting into the signal ground, and thus affecting the audio signal.

It also presents a low AC impedance to the op amp feedback divider, so that the unit's frequency response is not affected by the resistors used to generate the signal ground rail.

Before construction

Before you start assembling the board, if you're going to be fitting it in a UB5 Jiffy box, place the board in the bottom of the box and use a marker to place dots in each location where a mounting hole is required.

We've provided four different PCB overlay diagrams, to show you what components you need for each of the supply configurations.

Fig.5 shows the components required for a transformer with a single secondary (including most AC plugpacks) and Fig.6 for a transformer with two secondaries connected in series, or a single centre-tapped secondary.

Fig.6 also applies if you have a transformer with individual secondaries (eg, two 9V or two 12V secondaries). In this case, the phases of the windings need to be correct: the end of one secondary is connected to the start of the other secondary to effectively form a centre-tapped winding.

You need to be careful with this connection – measure across the two windings (ignoring the centre tap) to ensure you have twice the individual winding voltage.

If you get 0V (or close to it) you have connected the two windings incorrectly.

Where a split DC supply is called for (eg, $+15-0-15V$) use the overlay shown in Fig.7, whereas a single DC supply uses the overlay shown in Fig.8.

So let's get building!

Start by fitting the smaller resistors. While these have colour-coded bands indicating their values (as shown in the parts list), because certain colours can look similar depending on your lighting, it's much safer to measure their values with a multimeter before installing them. Use the appropriate overlay diagram as a guide as to which resistors go where.

Next, fit whichever of diodes D1-D4 are required for your particular configuration, followed by zener diodes ZD1 and (if needed) ZD2. In each case, ensure that the cathode stripe faces in the direction shown on the overlay diagrams, ie, towards the top or left edge of the board.

Now install the 1W resistor(s) and a socket for IC1, assuming you're using one. You can then mount the two $100\mu F$ capacitors and single $100nF$ capacitor. None of these are polarised.

Follow with the terminal block, if you're going to be using it, ensuring that it is pushed down flat onto the board and that its wire entry holes face the nearest edge.

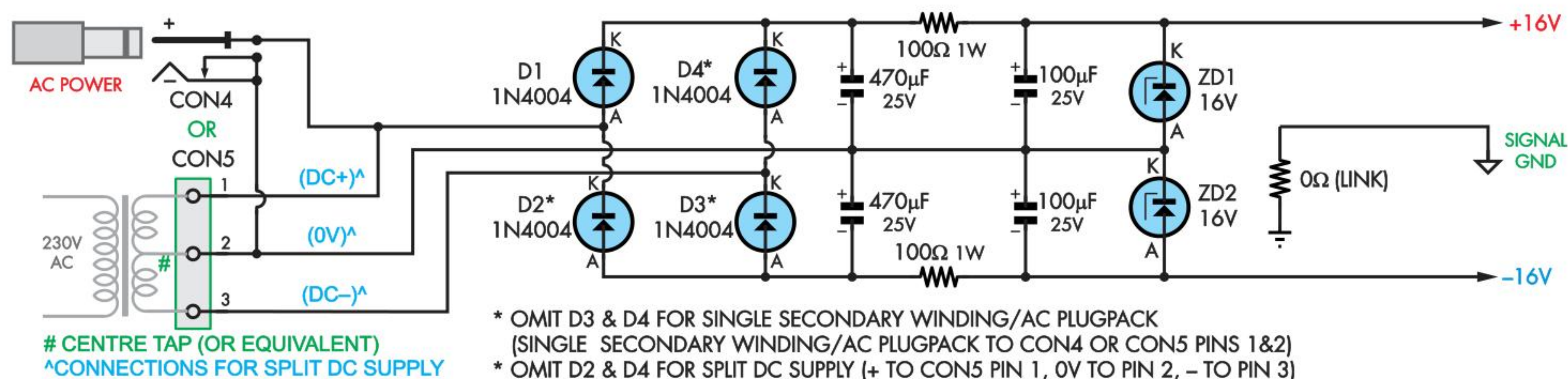
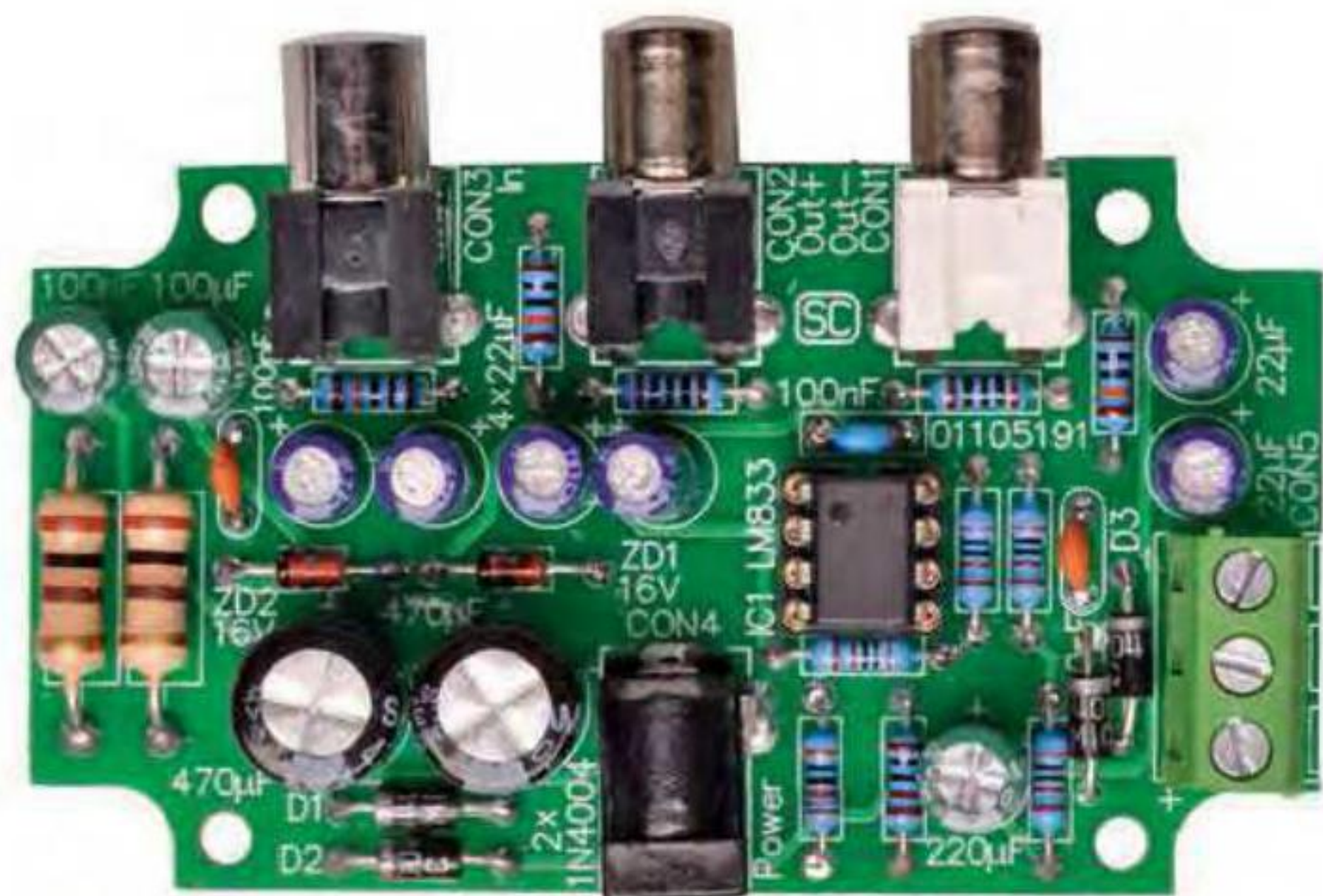


Fig.3: this shows a 'universal' power supply, suitable for a single ended DC input, a split DC input (ie, $+V/0V/-V$) or an AC transformer with or without a centre tap. CON4 is used for single-ended DC or AC since it only has two contacts. CON5 is used for split DC or an AC transformer with centre tap.



This photo of the PCB actually has all the power supply components shown in the four overlays. Some are obviously not necessary, depending on the version you build. (Use the component overlay for your version).

You can use a 3-way terminal block for all four configurations; however, with two of the configurations, only a 2-way block is required as shown in Fig.5 and Fig.8.

If using a two-way block, make sure to solder it to the right pair of pads.

Now fit the electrolytic capacitors. These are polarised and must be oriented correctly. The longer (+) wires go into the pads marked with a '+' on the PCB, towards the top edge of the board. The striped side of the can shows the negative terminal, so the stripes should all face towards the bottom edge.

There are three different types of electrolytic capacitors used, so don't get them mixed up.

Finally, fit the RCA terminals and DC socket (if required). In each case, make sure the connector is pushed down fully onto the PCB and lined up nicely with the PCB edge before soldering its pins. Be generous with the solder, as these pins are quite large.

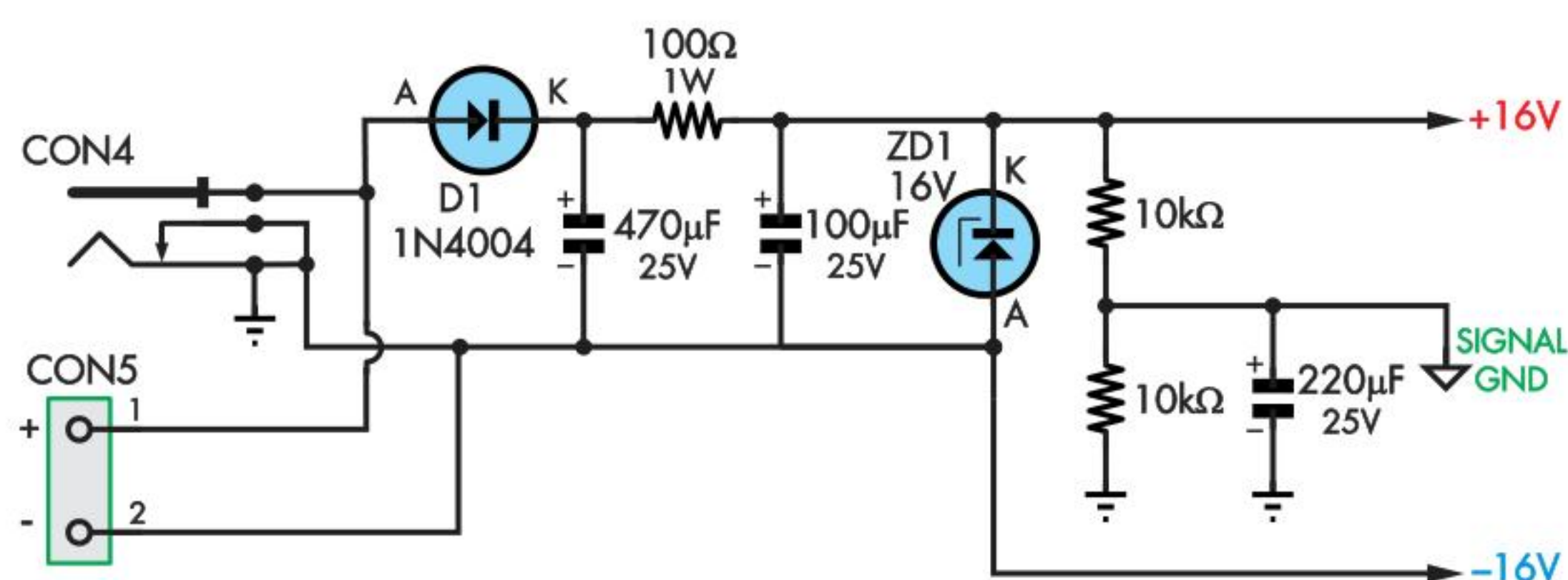
Testing

Before mounting it, it's a good idea to test the unit. If you've fitted a socket for IC1, you can leave IC1 out until you have verified that the power supply is working OK.

It's best to test the unit with the same type of supply that you will eventually be using; however, if you intend to use a centre-tapped transformer or split supply, you could use a 9-16V AC plugpack for initial testing.

Apply power and measure the voltage between GND (eg, the RCA connector shells) and pin 8 of IC1 (or its socket). If using an AC supply, you should get a reading of around +16V DC, or perhaps slightly lower if your AC supply is below 12V. Similarly, pin 4 of IC1 should be at around -16V DC. Pin 5 should be close to 0V.

If you're using a DC split supply, you should measure voltages at pins 8 and 4 of IC1 that are around 0.7V less than the applied voltages, while pin 5 should be close to



Power Supply (Single-ended DC)

Fig.4: the power supply can be much simpler when the unit is only to be operated from a single-ended DC supply. Some components are omitted while others have their values changed. The negative supply rail for dual op amp IC1 is connected to 0V via a wire link, while the signal ground is biased to half supply by a pair of resistors and a capacitor.

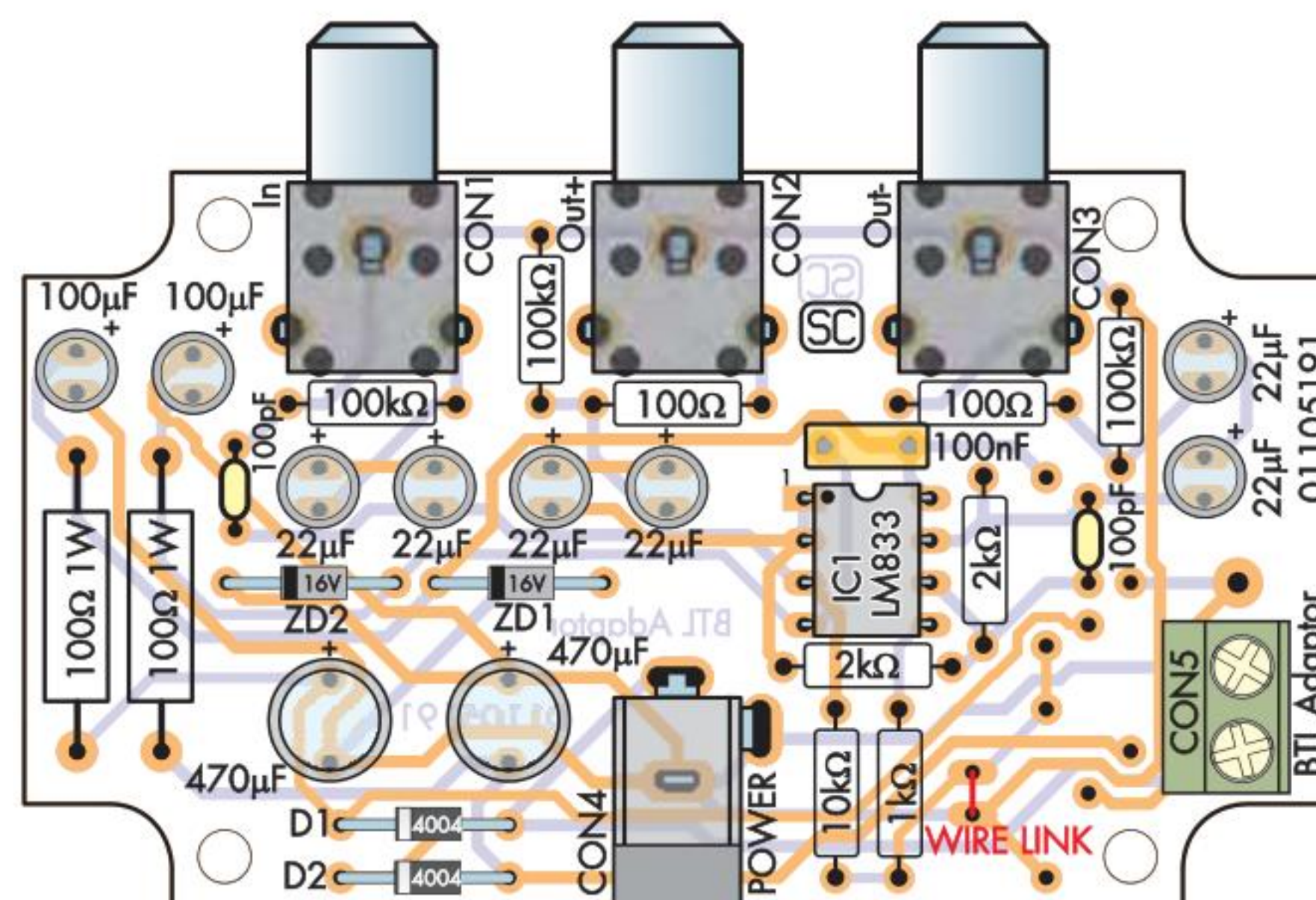


Fig.5: the overlay for a single AC supply, from either a 9-16V transformer or plugpack, plugged into CON5.

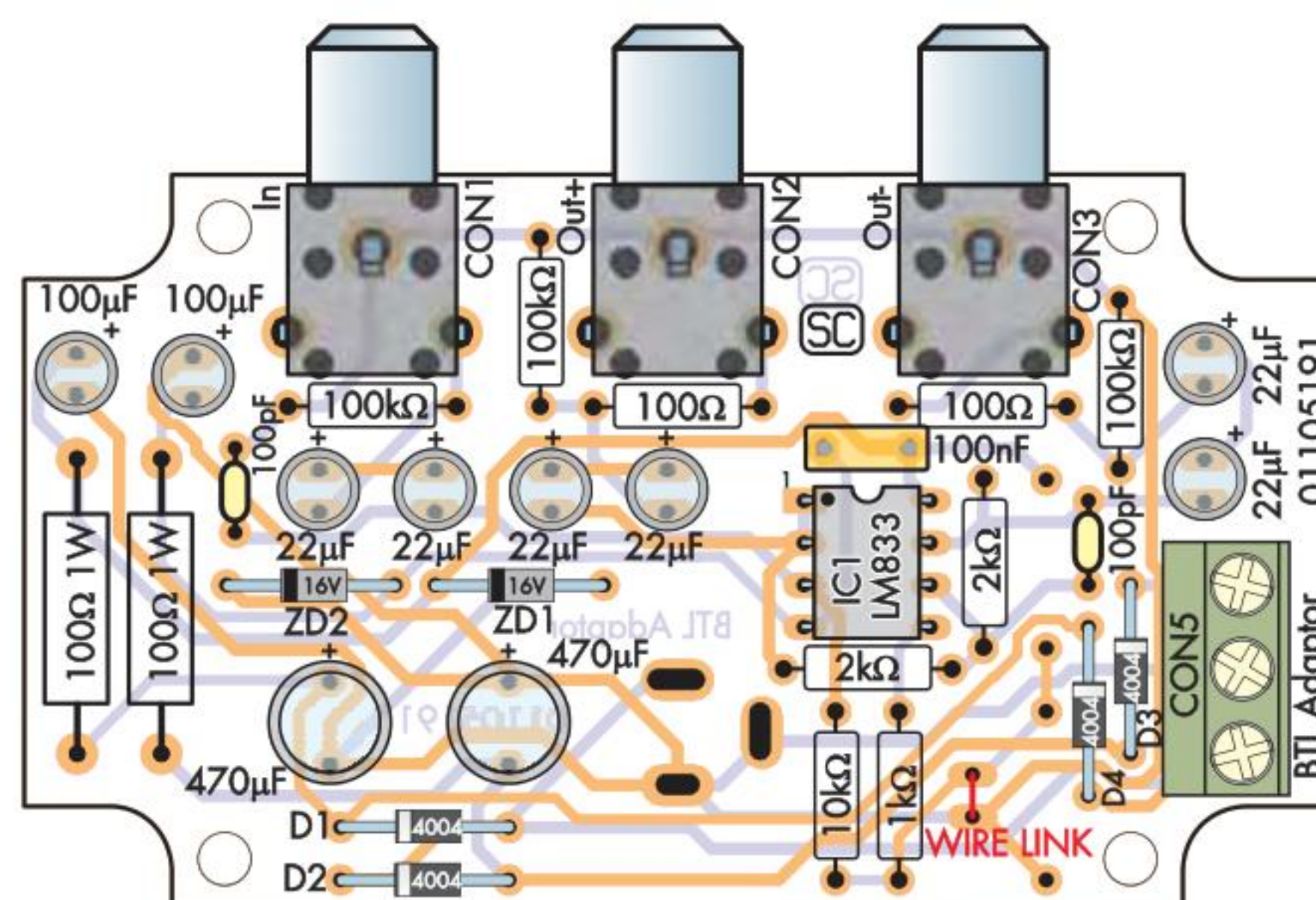


Fig.6: if you have a transformer with a centre-tapped secondary, use this overlay.

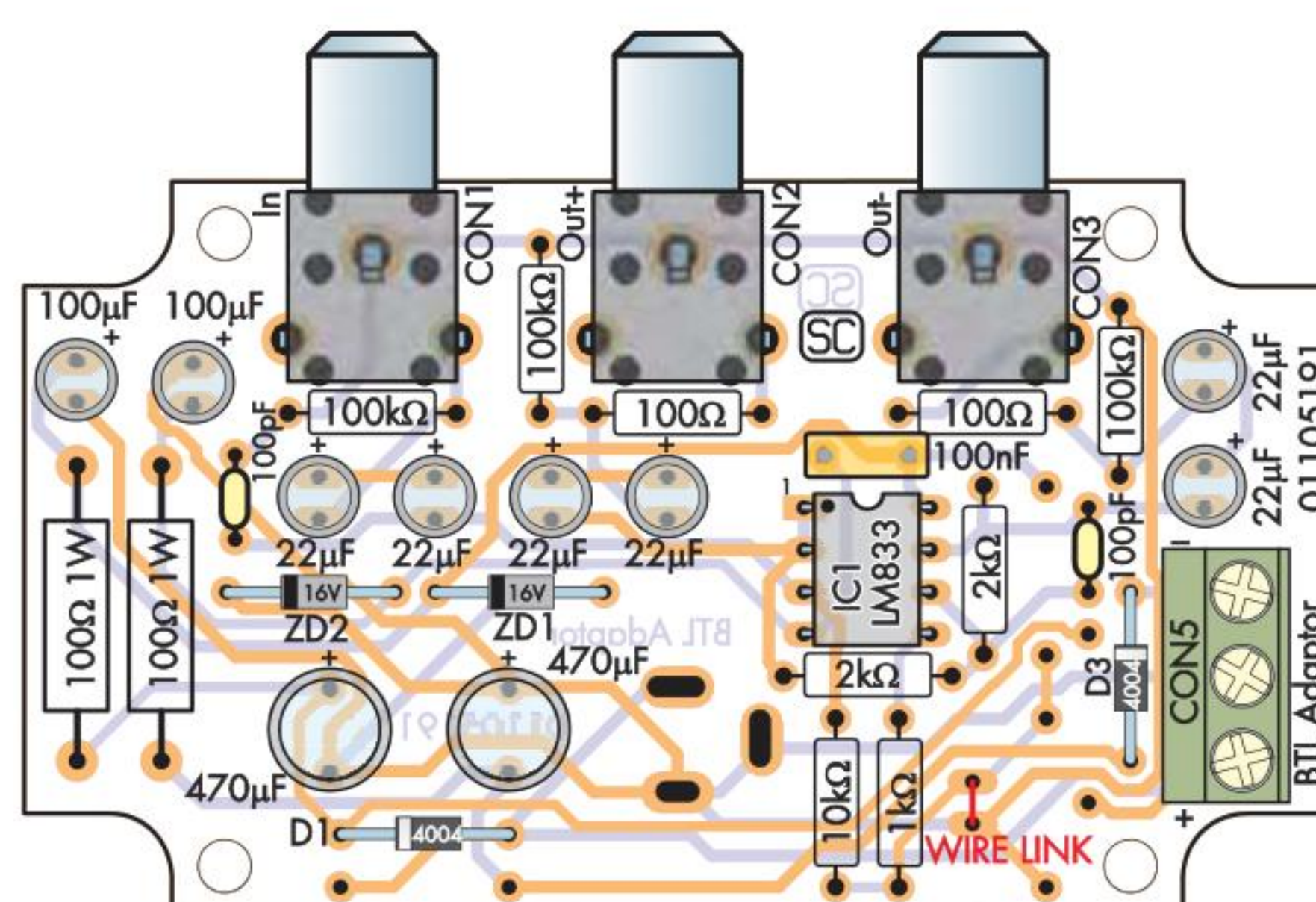


Fig.7 if you have a split DC supply (eg, ±15V and 0V) you will connect it to CON5 and omit some components.

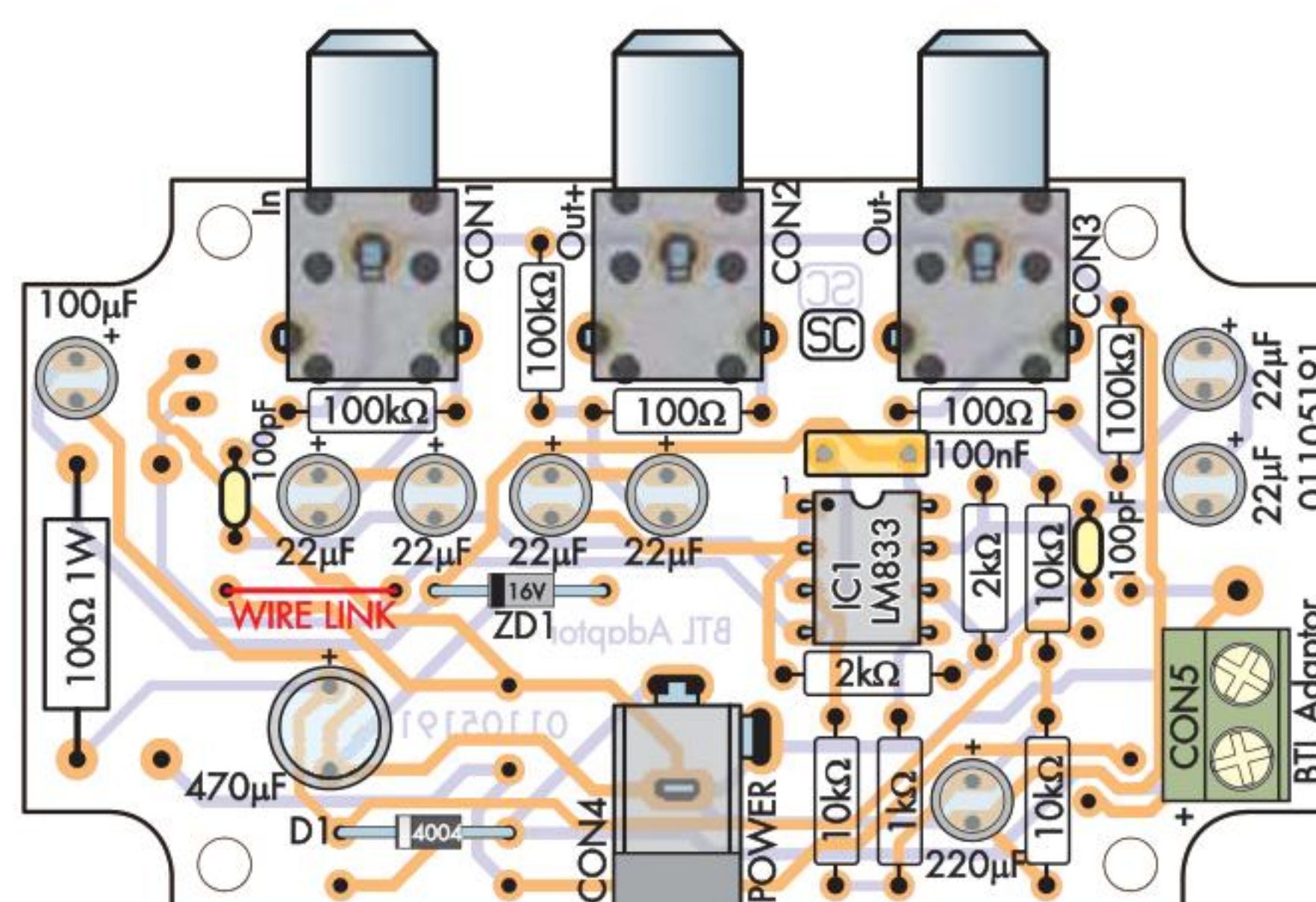


Fig.8: this overlay is for the single-ended DC supply, as shown in the circuit diagram at left.

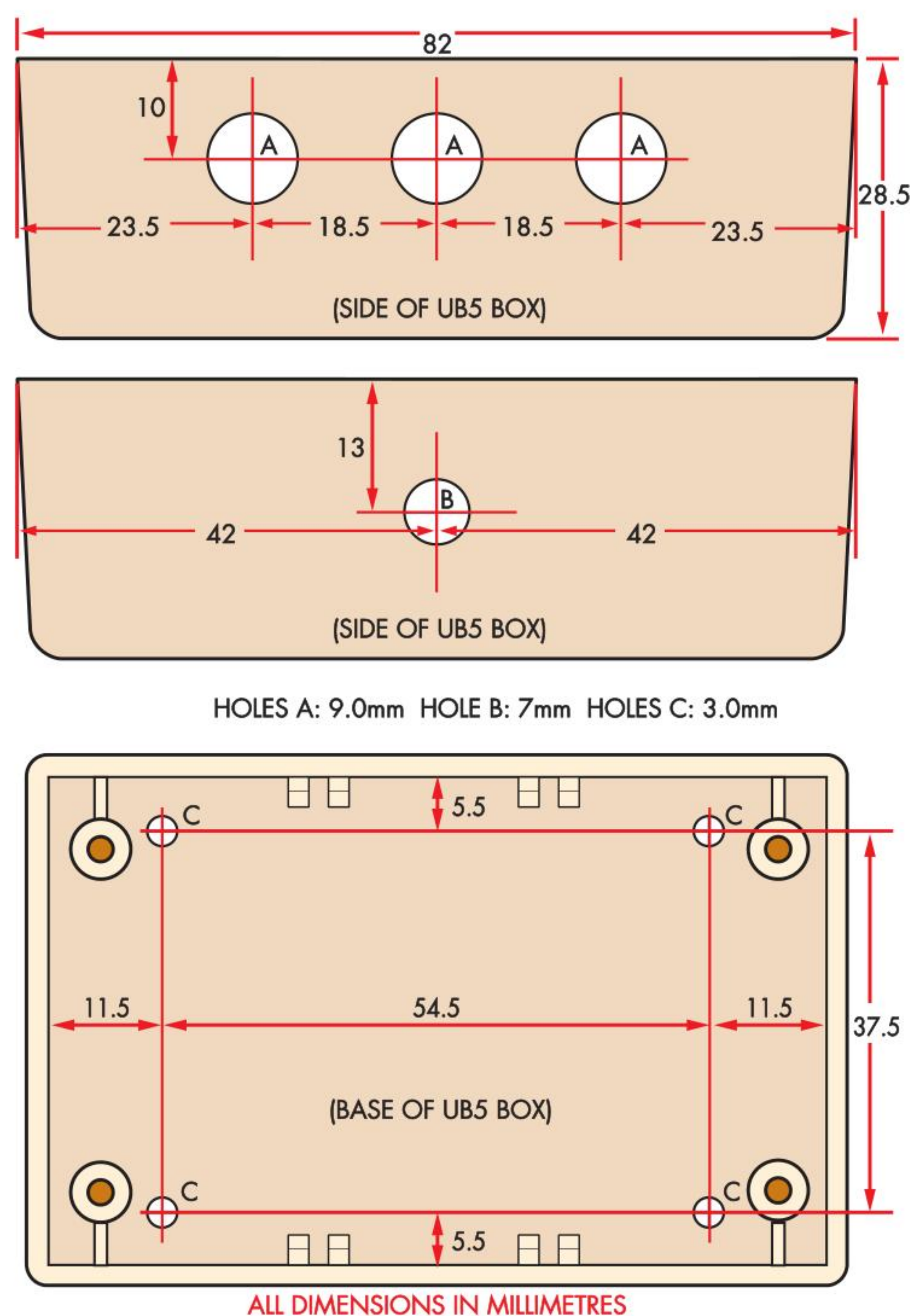


Fig.9: if you're mounting the *Bridge-mode Adaptor* in a UB5 Jiffy box, here's where to drill the holes required in the sides and base. The PCB is attached to the base using untapped spacers and machine screws (see parts list and text).

0V. And if using a single-ended DC supply, pin 8 should be around 0.7V less than your applied DC voltage, while pin 4 should read 0V and pin 5 should be almost exactly half the reading at pin 8.

If you get readings that are significantly different from those described above, switch off power and check your board carefully. Things to look out for are bad solder joints, incorrectly oriented components or components that are in the wrong location.

If the power supply checks out, switch off power, short out pins 4 and 8 of IC1's socket briefly (to discharge the capacitors) and then insert IC1 in its socket. Re-apply power and apply a signal to CON1, from a Blu-ray player, iPod, mobile phone, PC or whatever's convenient. Connect CON2 to the input of an amplifier with its volume set to minimum, then slowly ramp its volume up.

You should hear the input signal being reproduced cleanly. Disconnect CON2 from the amplifier and connect CON3 instead. You should again hear the input signal being reproduced cleanly (the fact that its phase is inverted will not be audible).

You can now do a final test, with CON2 hooked up to one amplifier input and CON3 to another, and the speakers connected across the amplifier outputs, as shown in Fig.1. Again, you should hear the signal loud and clear. Only this time, the maximum output power of the combined amplifiers will be much higher!

Mounting it in a box

As mentioned above, you will need to drill four 3mm holes in the base of the Jiffy box. If you forgot to do that earlier

(using the PCB as a template) you could instead make the holes where shown in the drilling diagram, Fig.9.

You will also need to drill three 9mm holes in one side of the box for the RCA sockets, plus a 7mm-diameter hole in the opposite side to access the barrel socket. The positions of these holes are also shown in Fig.9. You can copy (or download from the May 2020 page of the *PE* website) this diagram, cut out and stick the copy onto the box and then mark and drill the holes.

Ensure the template is aligned accurately with the top, bottom and sides and drill the holes accurately, starting with a smaller pilot drill and then enlarging to size with larger drill bits, a stepped drill or a tapered reamer. This ensures that the unit will fit nicely in the box and look neat.

Once you've made the holes, deburred them and removed any debris from the box, feed the four 16mm machine screws up through the bottom of the box and set it on a flat surface so they won't fall out. Next, drop the 6-7mm untapped spacers over the screw shafts and lower the board into the case.

To do this, first insert the RCA socket barrels through the holes in the case, then drop the opposite edge down into the box. You may have to push a little, getting the box to flex, to get it into place. Once all four screw shafts are through the holes on the board, use thin-nosed pliers to hold a nut on top and do up each screw one at a time.

This is a bit tricky since initially, the other three screws will be loose, so you can't just lift up the box, or they will fall out.

We did it by sliding one corner of the box over the edge of the desk while holding that screw so it couldn't fall out, then carefully rotating it so it threaded onto the nut, then moving on to another corner. Each nut you thread will make it easier to do the next one.

Alternatively, you could use Blu-tack, silicone sealant or some other type of glue to temporarily hold the untapped spacers over the holes in the box while you insert and do up the screws.

Do them all up tight, then put the lid on the box and affix the label. The artwork for the label can be downloaded from the May 2020 page of the *PE* website in PDF format and then printed out.

Mounting it in an amplifier

If you want to integrate it into an amplifier, this is quite easy. You can use longer tapped nylon spacers and mount it to the bottom of the chassis using eight short M3 machine screws.

It's then just a matter of wiring up the AC or DC power supply connections to CON5 and connecting the audio signals using cables terminated with RCA plugs.

You could make these with two RCA-to-RCA plug cables and then cutting them in half and stripping off the insulation.

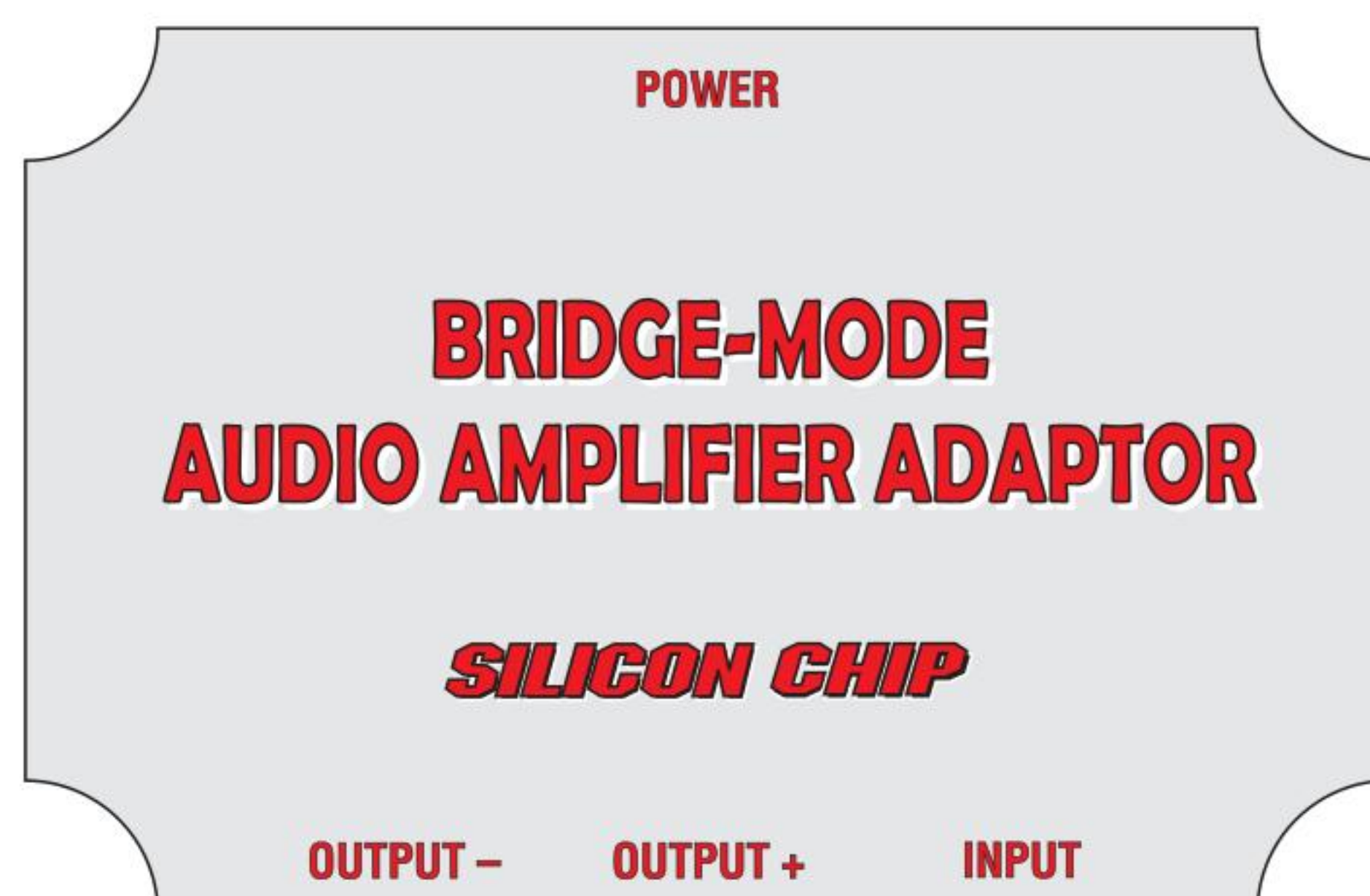


Fig.10: same-size label which fits the UB5 Jiffy box. You can download it from the May 2020 page of the *PE* website.



Here's what it looks like mounted in the UB5 Jiffy box, drilled as shown in Fig.9. If CON5 is used, access holes would also be needed on that side.



And here is the finished device, complete with a panel (see text). The beauty of this design is that no extra holes are required in the panel itself – they're all in the box sides.

Fig.11 shows how you can use a standard SPDT switch (toggle, latching pushbutton, rotary or slide) to allow the amplifier to be reconfigured as either stereo or bridged mono at any time.

Using it

If you've built the unit into an amplifier with the switch as described above, you can apply a stereo signal to the amplifier's left and right input channels, with the switch in the STEREO position, and it will operate normally as a stereo amplifier.

Or apply a single signal to the left input channel and put the switch in the MONO position, then connect a speaker wired as in Fig.7 for the bridged mono mode.

Or if you've built the unit into a Jiffy box, connect it to a stereo amplifier or pair of mono amplifiers as shown in Fig.1, for mono mode.

If you want to use the stereo amplifier in stereo mode, merely disconnect the unit and wire up the inputs and speakers as you usually would.

Reproduced by arrangement with
SILICON CHIP magazine 2020.
www.siliconchip.com.au

Parts list – Bridge-mode Adaptor for Amplifiers

- 1 double-sided PCB, code 01105191, 79 x 44.5mm
- 1 UB5 Jiffy box (optional)
- 3 PCB-mount right-angle switched RCA sockets (CON1-CON3)
- 1 PCB-mount right-angle barrel power socket (CON4) **AND/OR**
- 1 3-way (or 2-way) mini terminal block (CON5)
- 1 8-pin DIL IC socket (for IC1)
- 4 3mm inner diameter, 6.3mm-long untapped spacers
- 4 M3 x 16mm machine screws
- 4 M3 hex nuts

Semiconductors

- 1 LM833 or NE5532 dual low-noise op amp (IC1)
- 2 16V 1W zener diodes (ZD1,ZD2)*
- 4 1N4004 1A diodes (D1-D4)**

Capacitors

- 2 470µF 25V electrolytic*
- 1 220µF 10V electrolytic***
- 2 100µF 25V electrolytic*
- 6 22µF 50V electrolytic
- 1 100nF 50V multi-layer ceramic or MKT
- 2 100pF 50V NP0 ceramic

* only one required for single-ended DC supply

** only two needed for single AC/split DC supply

*** only required for single-ended DC supply

(code 100n, 104 or 0.1)

(code 100p or 100)

Resistors (all 0.25W, 1% metal film unless otherwise stated)

- 3 100kΩ (brown black yellow brown or brown black black orange brown)
- 3 10kΩ (brown black orange brown or brown black black red brown)
- 2 2kΩ (red black red brown or red black black brown brown)
- 1 1kΩ (brown black red brown or brown black black brown brown)
- 2 100Ω (brown black brown brown or brown black black black brown)
- 2 100Ω 1W 5%* (brown black brown brown or brown black black black brown)

All of these components are commonly available from your normal parts suppliers. The PCB (01105191) is available from the PE PCB Service.

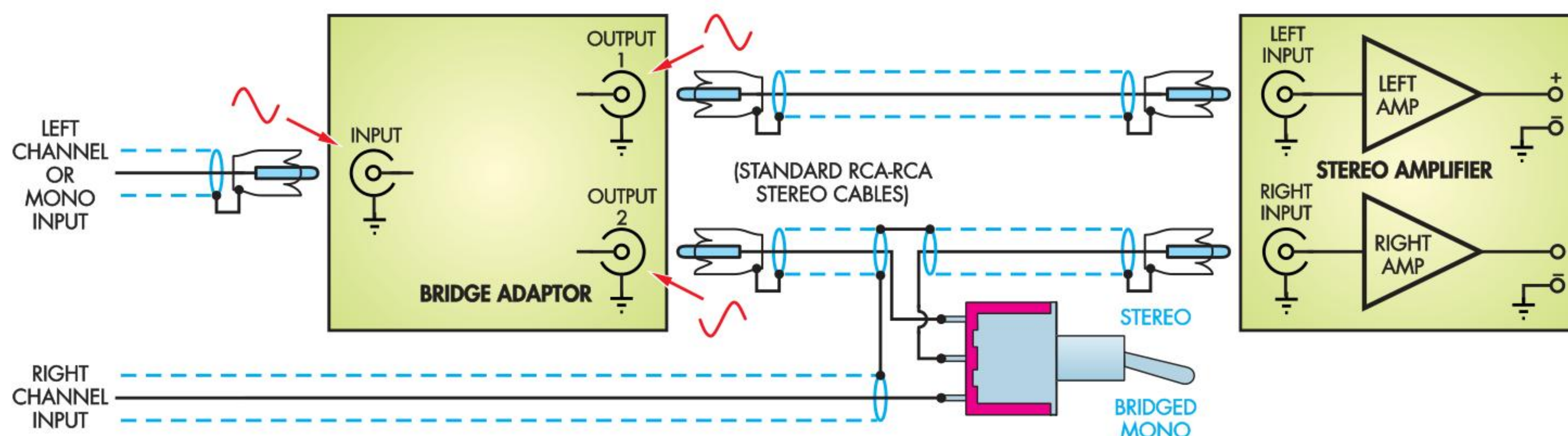


Fig.11: this is how you can use an SPDT switch to allow an amplifier to be easily reconfigured for either stereo or bridged mono. This makes a lot of sense when building the unit into an amplifier; when building it separately into a box, you can easily achieve the same result by re-plugging cables. The switch is shown here as a toggle type, but it could be a push-on/push-off, slide or even a rotary switch.

Want to give a project the retro-computer look? Or do you just need a convenient way to display a screen full of text on a low-cost monitor? Then this nifty project is for you. It generates a VGA signal akin to something from an early PC, or even a Commodore 64 or Amiga. It does this using a low-cost iCEstick FPGA development board and a very simple add-on board and is controlled via a serial port.



ICEstick

Part 2 – creating an FPGA VGA Terminal

Following on from our review of the iCEstick and IceStudio software in last month's issue, we wanted to see if we could do something more useful and exciting than flashing an LED.

After all, field programmable gate arrays (FPGAs) are considerably more capable than microcontrollers. So we had to think of an application that couldn't be done with a 555 timer IC or the most basic micro you can buy!

So we've come up with some 'code' which configures the FPGA chip (an iCE40HX-1k) on the iCEstick to generate VGA-compatible video signals using the eight digital outputs available on its PMOD connector.

The output is displayed as 16 rows and 32 columns of text, with selectable foreground and background colours for each 8×8 pixel character. The colours come from a palette of 16, chosen from 64 possibilities. The graphics ROM includes pseudo-graphics characters to create block graphics, boxes and shaded regions.

The module is controlled by a serial (UART) data line running at 9600 baud which accepts regular ASCII characters, LF, CR and FF control codes, as well as the pseudo-graphics above ASCII code point 127. There are also control codes to set the colours.

This project could be used as the starting point of a more ambitious FPGA-based project, or you could combine it with a microcontroller of your choice, using the serial port as your micro's display interface to the VGA monitor, to display text and graphics.

Note that when it comes to FPGAs, it no longer makes sense to refer to the code as 'software'. The IceStudio software takes our HDL (hardware description language) and synthesises it into a bitstream.

This bitstream could be considered an equivalent to a binary firmware image; it can be stored in a computer file or uploaded to an EEPROM on a target system. But rather than being a sequence of instructions

For this article, we're providing a complete IDE project which you can open up and use straight away. But it's also a great starting point for experimentation, and a wonderful tool for learning about how FPGAs work (and about digital logic in general).

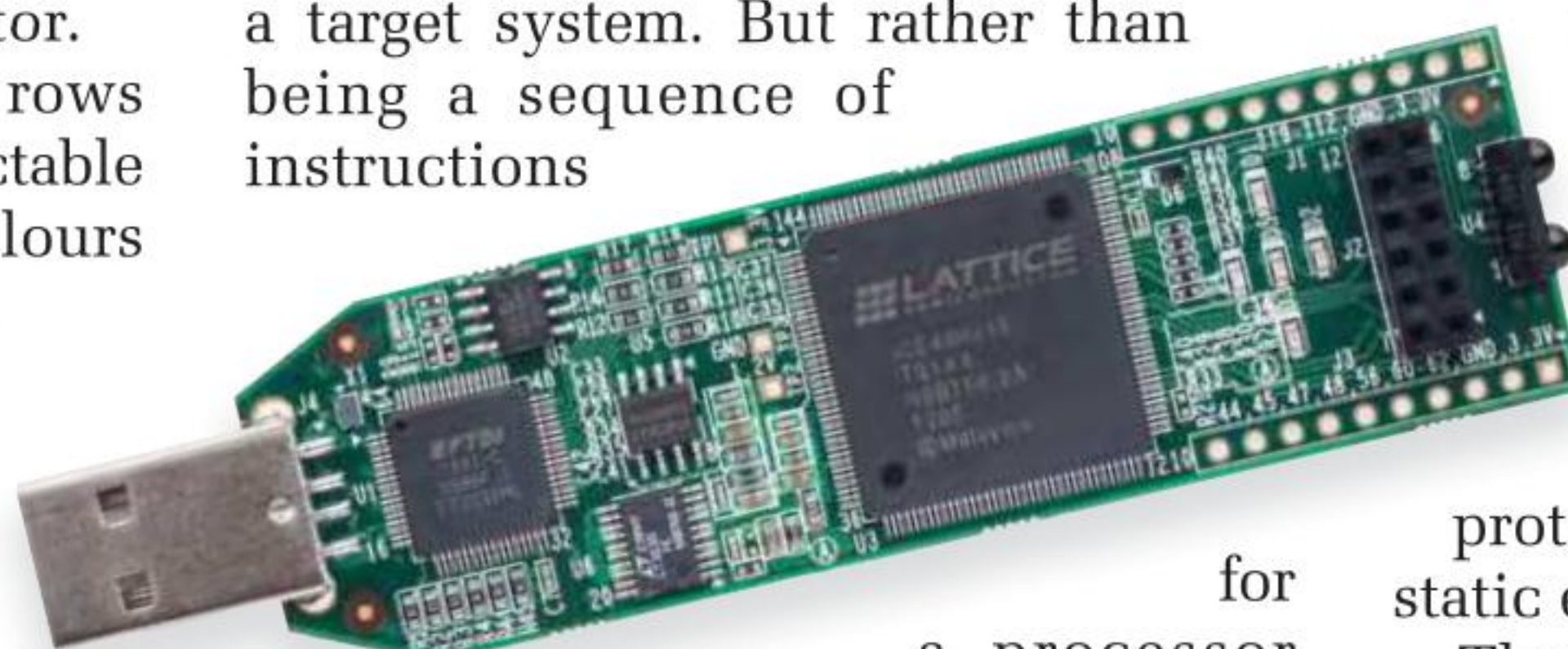
Circuit description

Most of the hardware required is on the pre-built iCEstick module. A small breakout board that we've designed plugs into the 12-pin PMOD connector, converting the digital signals from the iCEstick into signals which are fed to the VGA connector, to generate VGA video. The circuit diagram of this add-on board is shown in Fig.1.

The horizontal synchronisation (HSYNC) and vertical synchronisation (VSYNC) lines are effectively fed digital pulses via series resistors, which provide a degree of protection to the FPGA in case of static electricity and so on.

The red, green and blue VGA signals are formed by primitive 2-bit DACs, made using pairs of resistors in a 2:1 ratio, giving four evenly spaced voltage levels between fully off and fully on.

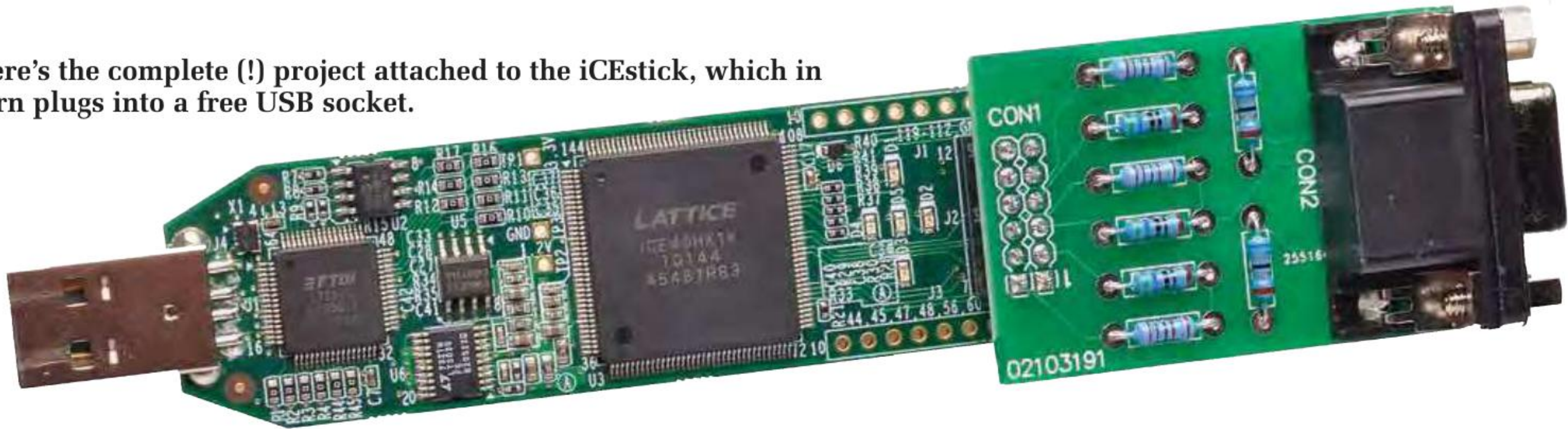
For example, if pins 3 and 9 of CON1 are held low (0V), then 0V is applied to pin 2 of CON2, the green signal. If both these pins are high (3.3V), then pin 2 of CON2 is at 3.3V. If pin 3 of CON1 is



for a processor to execute, it describes how the various elements within the FPGA are connected or configured. For more detail on this aspect, see last month's tutorial.

by Tim Blythman

Here's the complete (!) project attached to the iCEstick, which in turn plugs into a free USB socket.



high (3.3V) and pin 9 is low (0V) then the voltage divider formed by the 560Ω and 1.1kΩ resistors means that around 2.2V is fed to pin 2 of CON2, while if those voltages are reversed, pin 2 is at around 1.1V.

By using various combinations of levels on the red, green and blue lines, we can generate $4 \times 4 \times 4 = 64$ different colours on the screen.

The 560Ω and 1.1kΩ resistor values have been chosen to avoid exceeding the FPGA's 8mA per pin sink/source current rating. We found that on some monitors, this resulted in colours which were a bit dark, so you may wish to try slightly lower values (eg, 470Ω and 910Ω, or 430Ω and 820Ω). If you are unsure, stick with the suggested values.

All timing and signal generation is done within the FPGA. We won't claim the output is fully VGA compliant, but we have had no troubles using it with a few different monitors we tested.

Operating principles

We're generating a 640 × 480 pixel VGA signal, which involves scanning 800 × 525 pixels. The extra pixels are hidden in black borders outside the

normal display area of the screen (in the front/back porch and rescan areas). For a standard 60Hz monitor update rate, we need a 25.2MHz pixel clock ($800 \times 525 \times 60\text{Hz}$).

Our alphanumeric terminal occupies a central 512 × 384 pixel region of the 640 × 480 display image, with black borders around the edge. We've done this because the 512 × 384 pixel region maps to 32 × 16 alphanumeric characters, and $32 \times 16 = 512$ which is the number of bytes in each block of RAM within the FPGA.

It would be possible to combine multiple RAM blocks to allow a larger character display (possibly filling the screen), but that would complicate the code design somewhat. Making the relevant changes could be a good exercise for readers who really want to delve into FPGA programming.

The FPGA scans the 800 × 525 area, uses its video RAM to determine which character should be displayed at any given point, then uses the font ROM to determine whether the foreground or background colour should be displayed for each pixel. The HSYNC signal is pulsed at the end of each horizontal scan (ending a line), and

the VSYNC pin is pulsed every vertical scan (ending a frame).

Generating the clocks

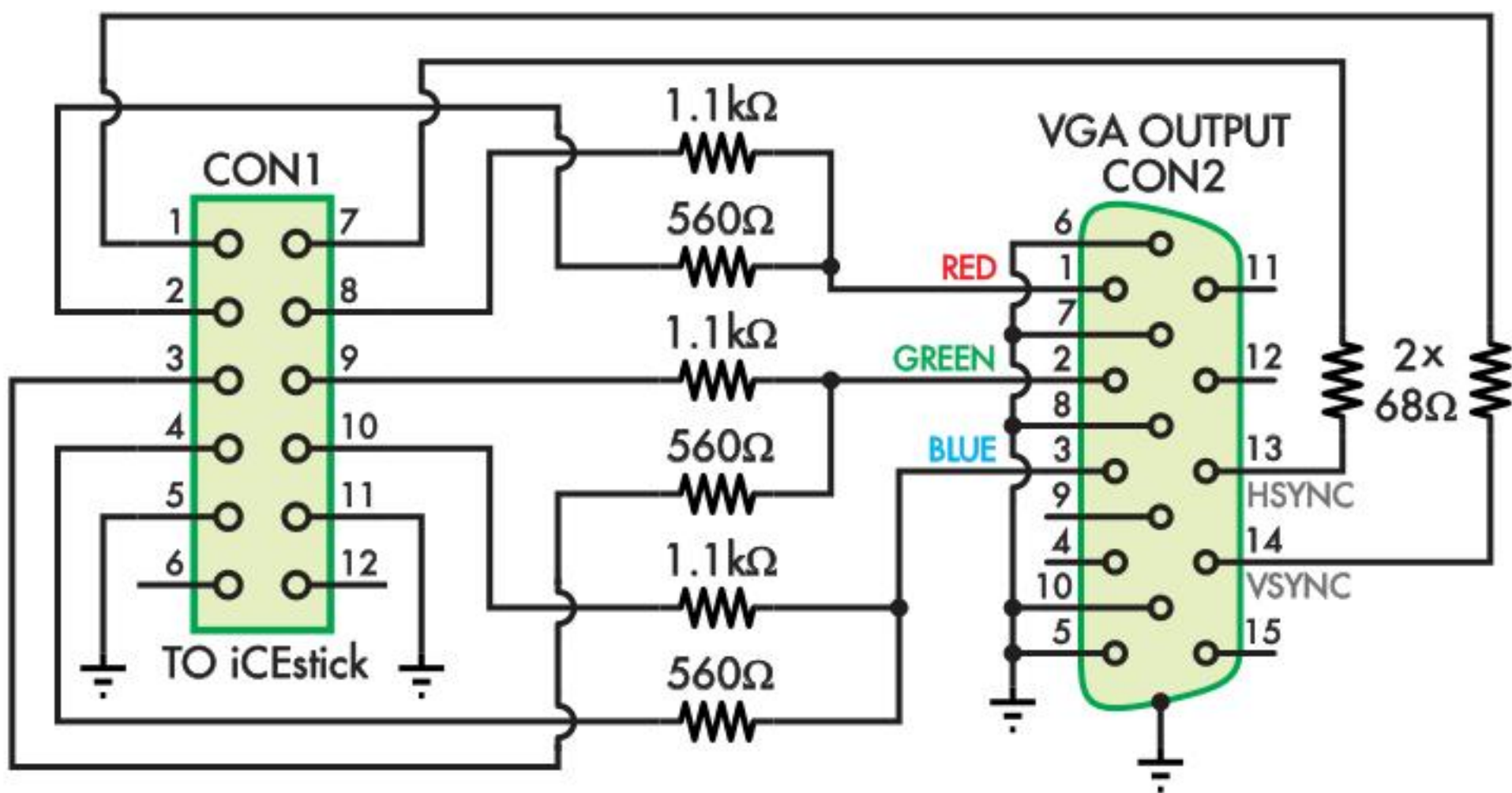
The iCEstick only has a 12MHz oscillator, so we need to use the iCE40HX-1k's phase-locked loop (PLL) to bring that up to around 25MHz. We are generating a 100.5MHz signal, which we divide by four to get 25.125MHz. This is the closest the PLL can get to our target frequency of 25.2MHz, using a 12MHz source. This small error doesn't end up causing any problems.

This clock signal is divided by a factor of 800 in the FPGA, to give a 31.4kHz line clock, then again by 525 to give the frame/screen refresh clock of 59.8Hz. That's 0.2Hz slower than our target of 60Hz, but it isn't uncommon to see video refresh rates that are not an exact number of hertz, and virtually all monitors will handle this.

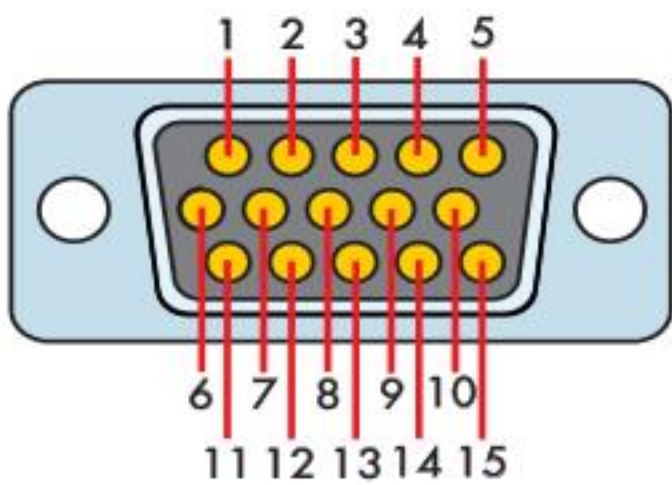
We have created a 10-bit horizontal pixel counter in the FPGA which starts at zero and counts up to 799, incrementing on each clock pulse (at 25.125MHz), then resets back to zero. Each time it resets, the 10-bit vertical pixel counter is incremented, and it's reset to zero as soon as it exceeds 524.

Fig.1: the circuit for our VGA Adaptor is delightfully simple, since so much of the hard work is done by reconfiguring the blocks inside the FPGA.

Three resistive two-bit DACs are formed by the 1.1kΩ and 560Ω resistors, to control the red, green and blue voltage levels on the VGA connector. The HSYNC and VSYNC pulses are digital signals fed straight to the VGA socket, with 68Ω series resistors for safety. The unusual pin numbering of CON1 is to match the numbering on the iCEstick; they are treated as two side-by-side SIL headers, even though it's physically a DIL header.



iCEstick VGA Adaptor



VGA socket – looking at pins.

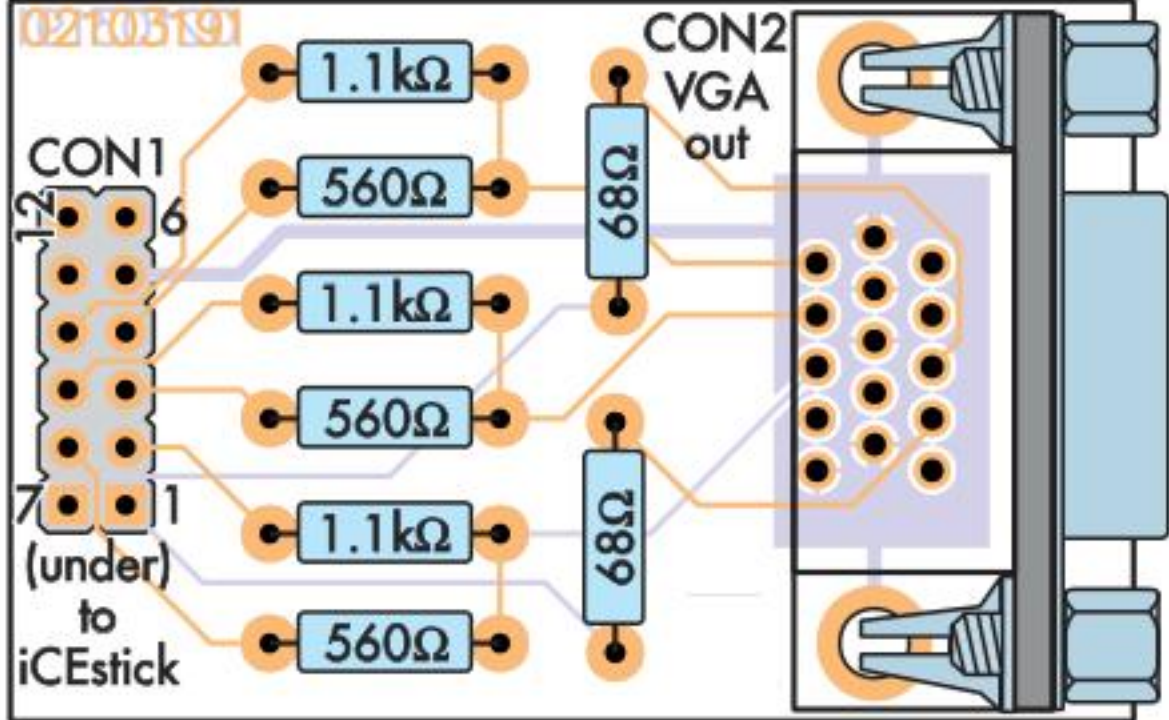
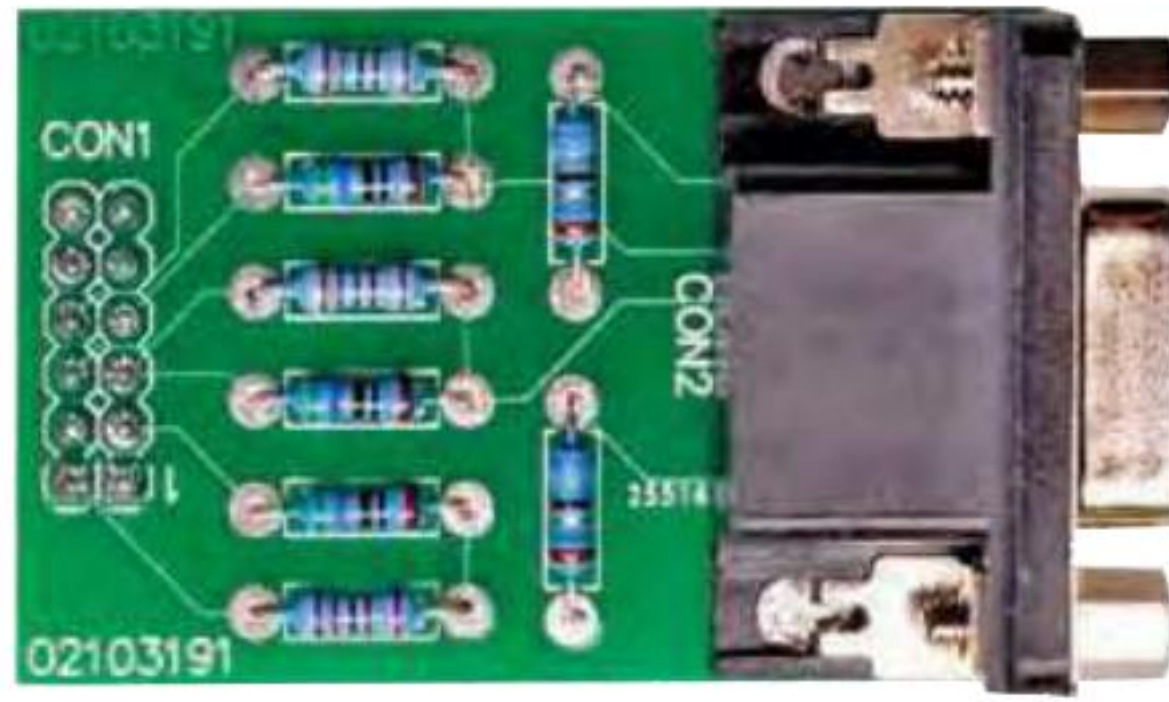
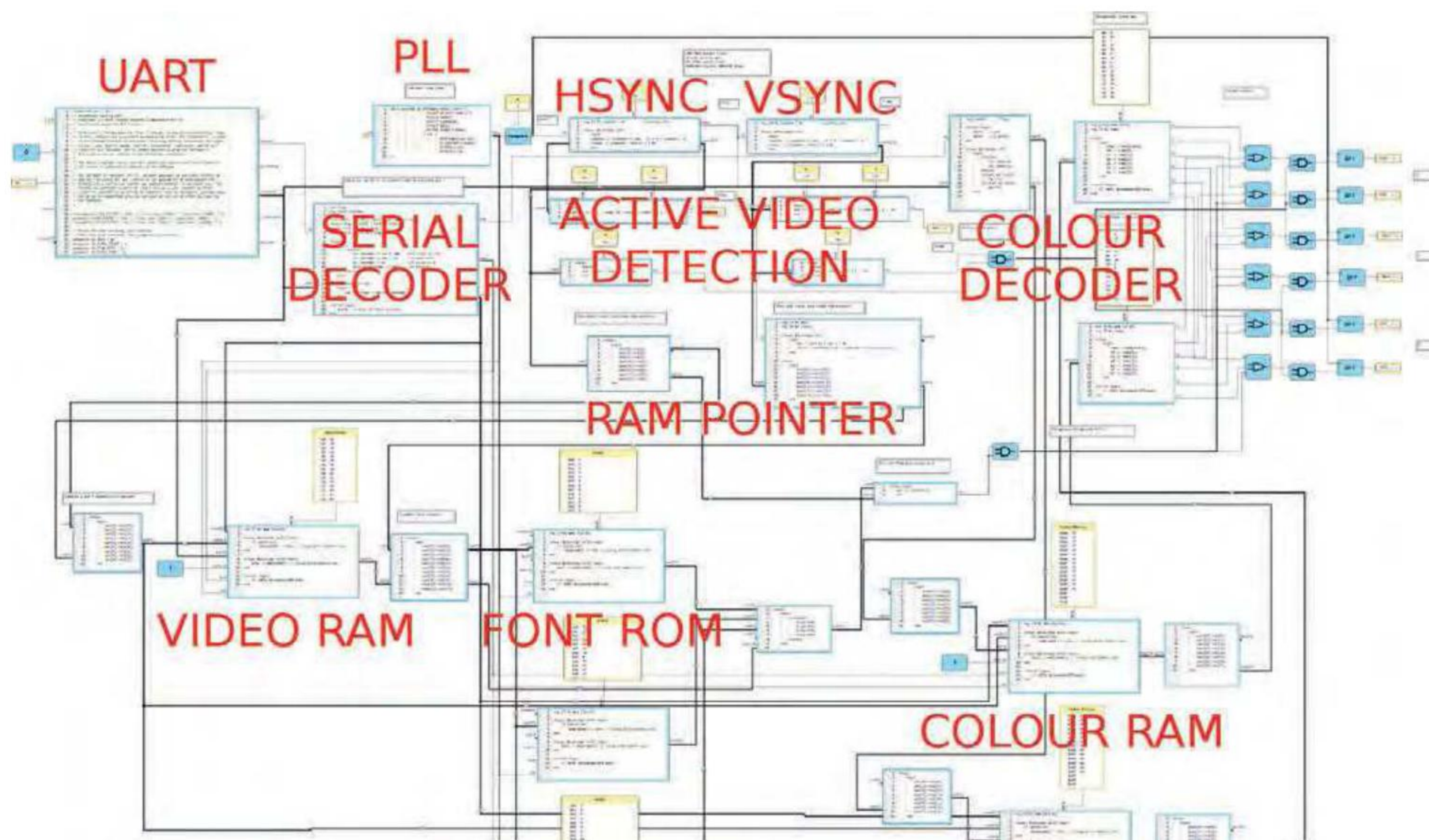


Fig.2: fit the resistors to the PCB as shown here, then the VGA socket, which goes on the same side as the resistors, and finally the 6 × 2 pin header, on the opposite side. The resulting assembly then plugs straight into the iCEstick and a standard VGA monitor cable.





Screen1: this is a broad map of the functional parts of the ‘iCEstick VGA Terminal.ice’ project. You will need to install IceStudio, download and open that file and zoom in to see the detail of each block.

So these two counters allow us to keep track of which pixel is currently being emitted.

When these pixel values are within the 512×384 active area in the middle of the screen, they are further divided by 16 (horizontal) and 24 (vertical) to determine which character position is currently being displayed. The FPGA then retrieves the 8-bit ASCII character value and two 4-bit colour (background/foreground) values from its video RAM.

The 4-bit colour values are then used to look up the 16-entry palette to determine the 6-bit colour values to use as the foreground and the background for the character currently being emitted. Similarly, the ASCII character value is used to look up an entry in the font ROM.

All these lookups culminate in a pixel colour value which is then fed to

the RGB outputs (pins 2-4 and 8-10). At the same time, the HSYNC (pin 1) and VSYNC (pin 7) lines are driven based on the horizontal and vertical counters, to generate the required sync pulses for the monitor.

In more detail, when the horizontal pixel counter is between 0-511, that is the active part of the display, and the RGB outputs are driven. The rest of the time, the RGB outputs remain low, so the front porch, back porch and borders are black. When the horizontal counter is between 592 and 688, pin 7 is set high, creating the HSYNC pulse.

Similarly, the vertical (line) pixel clock counts from zero to 524, with the RGB outputs active from 0-383, and VSYNC is driven high on lines 443-445. The lines between 446 and 524 are the vertical refresh period, so the RGB outputs remain low.

These sync values have been chosen by trial and error, to centre the display on our test monitor.

They can be changed in the FPGA configuration to adjust the location on your monitor, although the differences between the values should remain the same to maintain the same sync pulse widths.

Implementing this in the FPGA

We’re using the IceStudio software to demonstrate what can be done using this software, and while the IceStudio project looks quite complicated, it can be broken down into small, easy-to-understand functional blocks that each accomplish one small task.

We hope this gives you an insight into just how easy it is to jump into creating your own FPGA projects with Verilog inside IceStudio; do keep in mind as you work with FPGAs that the outcome is actually an arrangement of logic gates and flip-flops that all work simultaneously, rather than code that is processed in sequence.

Screen1 shows the IceStudio project in its entirety. The FPGA is configured by connecting various blocks together, and we’ve labelled groups of blocks to indicate their purpose. If you want to examine the design in more detail as we explain what each block does, skip to the section below titled ‘Installing the software on your computer’, then come back and read the following description.

128	64	32	16	8	4	2	1	Decimal	Hex
0	64	32	16	8	0	0	0	120	0x78
128	64	0	0	8	4	0	0	204	0xCC
128	64	0	0	8	4	0	0	204	0xCC
128	64	0	0	8	4	0	0	204	0xCC
128	64	32	16	8	4	0	0	252	0xFC
128	64	0	0	8	4	0	0	204	0xCC
128	64	0	0	8	4	0	0	204	0xCC
0	0	0	0	0	0	0	0	0	0x0

Fig.3: this shows how font glyphs are converted into bitmap values, by adding the value of the pixels that should show the foreground colour. IceStudio expects hexadecimal numbers in the font ROM, so you will need to convert the decimal sums to hexadecimal format (eg, using a ‘programmer’s calculator’).



Screen2: if you have successfully built the hardware and programmed the FPGA, you will be greeted by this display on your VGA monitor.

Clock generation is performed by the area marked PLL in the project window. The code in this block contains synthesiser directives that describe how to configure the PLL. The iCE-cube2 software that we reviewed in last month's *Part 1* is capable of generating PLL configuration data if you want to experiment with this block.

To the right of the PLL block and left of the HSYNC/VSYNC sections are the clock dividers.

The small blue block divides the 100.5MHz clock by four to give the 25.125MHz pixel clock, which is then divided by 800 to give the line clock. This is in turn divided by 525 to give the frame clock.

The ACTIVE VIDEO DETECT section compares the pixel and line clocks to the fixed values indicated above, producing two outputs which are both high when the current pixel is part of the 512×384 pixel active area. These are fed to the colour decoder, which generates black unless both (horizontal and vertical) active video bits are set.

Below ACTIVE VIDEO DETECT is a section which divides the pixel count by two to create indexes for the font ROM. The line count is effectively divided by three, to create the vertical font index. But rather than using a divider, which would be quite large and complex to implement in the FPGA, instead, a separate counter is used, which is only incremented on every third pulse from the line clock, then reset when it reaches 128 (ie, $384 \div 3$).

Serial data handling

The FPGA needs to accept serial data from the host, both for configuration and to update the displayed characters and/or colours. The UART block is shown to the left of the PLL in Screen1. This is made using open-source Verilog code that is available at <https://github.com/cyrozap/osdvu>, which also includes a description of how to interface to it.

We don't need to send any data back to the host, so we removed the

transmit-specific sections, to save FPGA resources.

While a microcontroller would wait and then branch to code to read from a buffer when the host is sending data to it, the FPGA is always ready to react, and the data from the UART is put into the video RAM within nanoseconds of it arriving, simultaneously with the video output tasks occurring elsewhere on the chip.

The UART decoder filters the incoming serial data and also holds a video RAM pointer. This filtering checks the three high-order bits of each received character. If all of these are low, then the received serial data ASCII value is less than 32. That means that it is a control byte and processed as such.

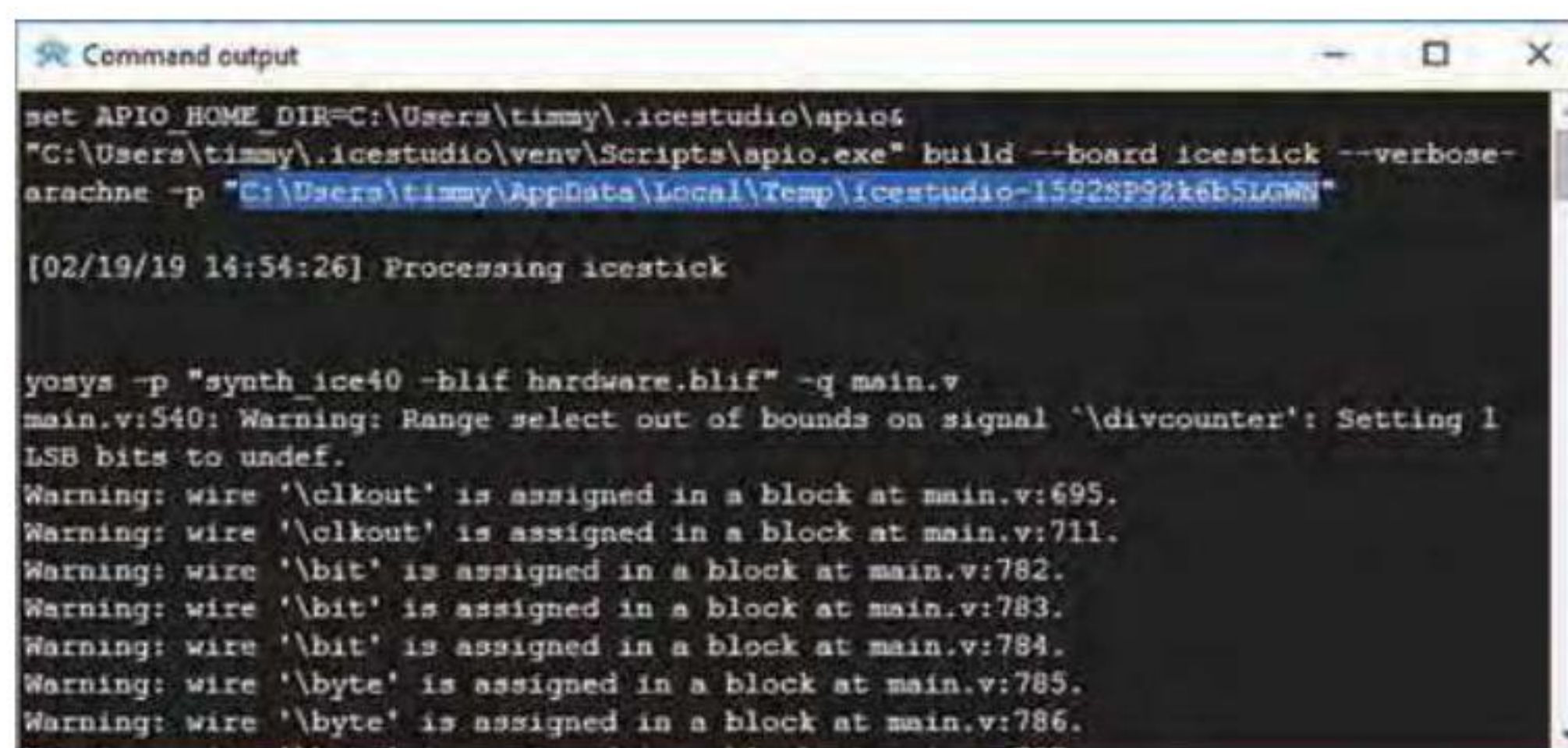
The control bytes work as follows. A carriage return (code 13) causes the video RAM pointer to be reset to the start of its line by ANDing its value with 32. A line feed (code 10) moves the pointer to the next line by adding 32, and a form feed (code 12) moves the cursor to position zero by resetting the pointer, as though starting a new page.

If the received data value is 32 or higher (and thus an ASCII character), the received character is written to the video RAM at a position corresponding to the pointer's value and the pointer is incremented by one. Thus, characters received consecutively appear at consecutive locations on the display.

The currently selected foreground and background colour combination is also written to a separate RAM which is used to later decode the colour data for display.

Other control codes are decoded by the small block to the left of the colour decoder. Code 14 sets a flag so that the background colour is set, while code 15 sets the flag to the foreground. If a value from 16 to 31 is received, it is sent to the foreground or background register per the flag.

Because all except the lower four bits are ignored here, code 16 selects colour 0 and code 31 selects colour 15 from the palette.



Screen3: in the window that appears after clicking View → Command Output, the folder containing the generated Verilog file is visible (highlighted section). Open this folder and find the file named 'main.v', which is the generated Verilog equivalent of the IceStudio project.

Screen6 shows the default palette of colours that are available.

The video RAM section takes an address value made from combining parts of the horizontal and vertical 'scan' position. The small code box on the left just combines the bits to create a linear address.

Video RAM

The larger box is the video RAM itself. This has been coded in a specific way to use part of the iCE40HX-1k's BRAM (block RAM). If not done in quite the right way, the memory is synthesised from flip-flops instead of using the dedicated block RAM. This alternative is a very poor use of resources; as an experiment, we tried this, and found that the 512 bytes of RAM took about half of the FPGA's flip-flop resource.

The iCE40HX-1k contains 16 separate 512-byte blocks of double-ported RAM. The double-port feature means that it can be read and written at the same time, which is essential in our application because we may be trying to change the display at the same time that the VGA display logic is reading from it (as it is reading video RAM almost constantly).

The small beige block above the video RAM initialises it at startup to display some splash-screen text. If you

Parts list iCEstick VGA Terminal

1 Lattice iCEstick FPGA development board

[Mouser 842-ICE40HX1KSTICKEV, Digikey 220-2656-ND]

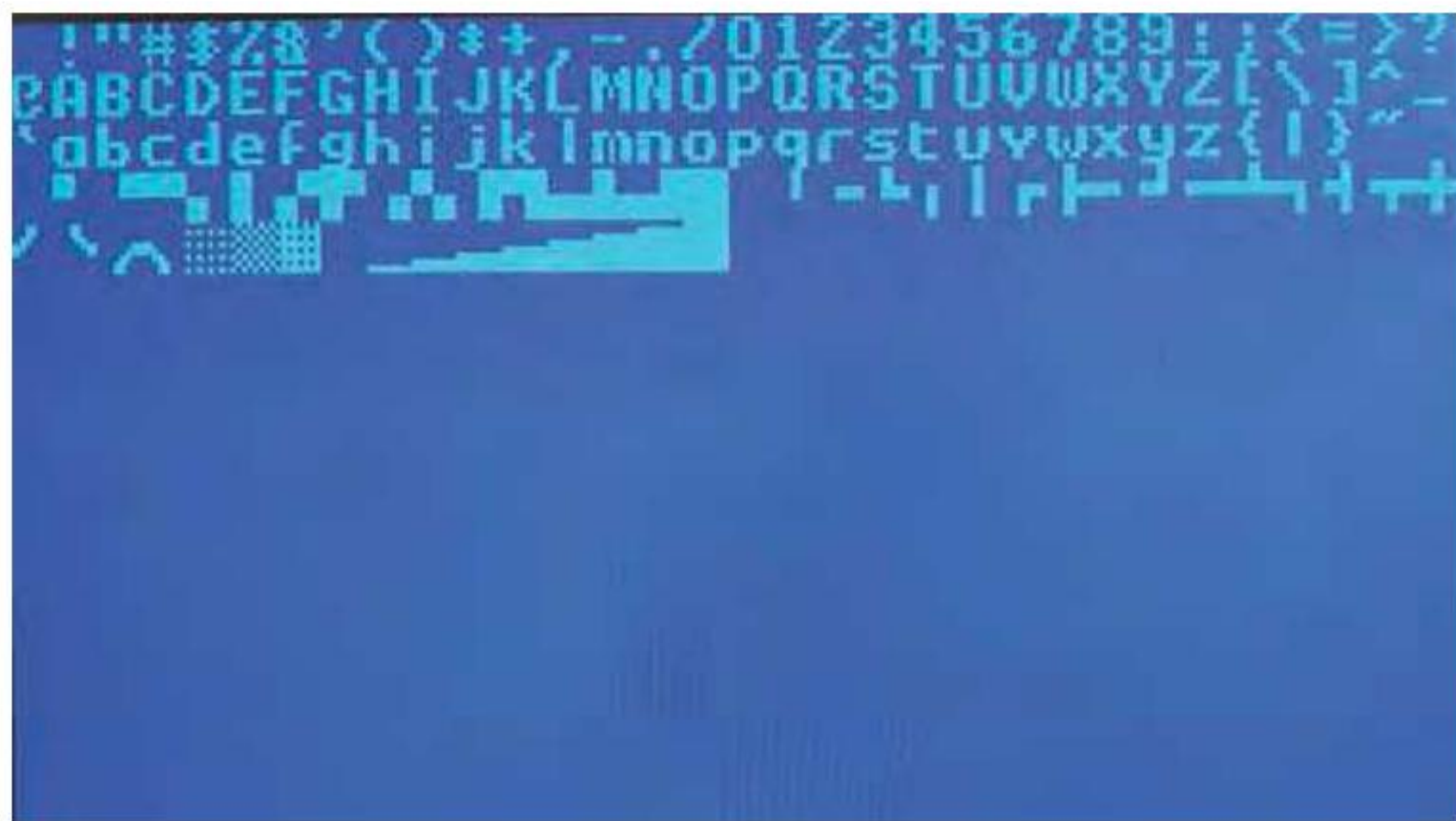
1 double-sided PCB, code 02103191, 49.5 x 32mm [PE PCB Service]

1 2x6 male pin header (CON1)

1 DE-15 (or HD-15) high-density 15-pin female D-connector (CON2) [AMP 1-1734530-1, MULTICOMP SPC15430]

Resistors (all 1/4W 1% metal film)

3 1.1kΩ 3 560Ω 2 68Ω



Screen4: the default character map/font for the iCEstick VGA Terminal. It can be changed by editing the font ROM blocks. The first three lines are the standard ASCII characters at positions 32-127, followed by some pseudo-graphics characters that can be used to draw boxes, bar graphs and so on.

don't want this, replace the contents of the beige block with zeroes, or your own hexadecimal values for a custom splash screen.

The small block to the right of the video RAM generates an address into the font ROM, based on the displayed character value from video RAM and the vertical position of the scan.

Font ROM

The font ROM consists of three BRAM blocks, each fed by a separate initialising block. While implemented using RAM blocks, there are no connections to the write lines, so they remain unchanged as long as the FPGA is powered, and are effectively read only.

By using multiple BRAM blocks and a four-way multiplexer, we can overcome the 512-byte limit of each block (hint: this might be a good way to expand the video RAM). Each BRAM block encodes 64 characters in eight bytes each, for a total of 512 bytes. There's room to add a fourth BRAM block below, but we only need 192 characters in the font ROM, so we have not done so.

Each byte of the font ROM encodes a horizontal line of eight pixels as a bitmap. The small block next to the font ROM decodes the horizontal character sub-position into a single bit; it is effectively an eight-to-one multiplexer. The output of the font ROM is a single bit indicating whether the foreground or background should be displayed for the current pixel.

Colour

In a similar fashion to the way the video RAM is read, data is read from the colour RAM to determine the combination of foreground and background colours to be displayed at the current scan position. This is a separate RAM block that uses the same address and clock lines as video RAM as its input.

The output of the colour RAM is fed to the colour decoder.

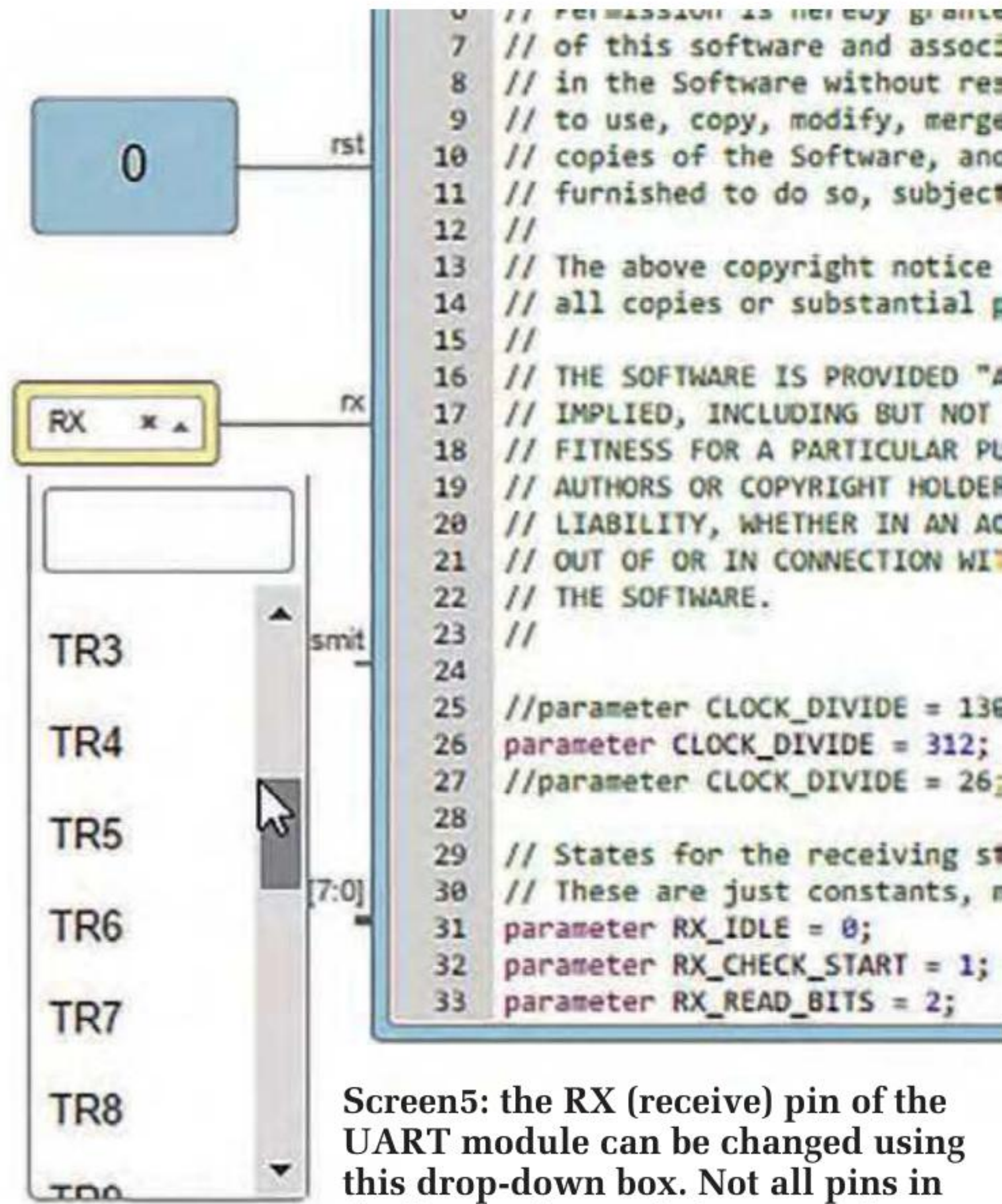
The colour decoder has a pair of small 6×16 bit ROMs, which are initialised by the beige blocks above them. These decode the 4-bit colour palette index value into the necessary output pin states to generate that specific colour in the palette. The two blocks are identical; one is used to decode the foreground colour and one the background colour, to simplify the following logic.

The colours have been chosen based on those used in the venerable Commodore 64, which also had a 16-colour display.

To the right of the ROMs are a row of multiplexers, one for each output pin involved in driving the VGA colour lines. The multiplexer chooses between the foreground and background colours according to the line from the font ROM.

This is followed by an AND gate. The data from the multiplexer is ANDed with a bit that indicates if the current scan position is inside the central 512×384 pixel box, in which case the foreground or background colour is produced. Otherwise, the result is low, so the outputs of all the AND gates are low and therefore all the output pins are low and black is displayed.

Finally, a D-flipflop is used to buffer this signal into the output pins, so that their states only change on the pixel clock. This ensures our pixels are not subject to jitter and thus line up squarely on the screen. The result is a very stable display.



Screen5: the RX (receive) pin of the UART module can be changed using this drop-down box. Not all pins in the list can be used; for example, we are already using all the PMOD pins for the VGA output.

Installing the software on your computer

To build this project, you need to install the IceStudio integrated development environment (IDE) software. There are versions available for Linux, Windows and macOS. If reading last month's *Part 1*, an FPGA tutorial, then you may have already installed it. Otherwise, follow the installation instructions at: <https://github.com/FPGAwards/icestudio>

We used version 0.4.0. Once installed, you should also install the toolchain and enable the driver for the iCEstick (only needed on Windows).

If you're unsure how to do this, read the aforementioned tutorial, which explains this in detail, or read the IceStudio documentation at: <https://icestudio.readthedocs.io/en/latest/>

Now download the **iCEstick VGA Terminal.ice** file from the May 2020 page of the *PE* website and open it in IceStudio. You will see something similar to what's shown in Screen1, and you can now examine the blocks in closer detail.

If you need to change any of the configuration parameters, such as the serial port baud rate, these are 'hard coded' into the project, so you will need to change the .ice file using the IDE graphical interface.

Other settings that can be changed include the colour palette and font glyphs. Details on how to change all these parameters are given below.

By default, the serial interface is connected to iCEstick's USB/serial



Screen6: these are the colour combinations that can be displayed by the iCEstick VGA Terminal. The characters shown at each column are combined with the Control key to create the foreground colour shown in many serial terminal programs. These 16 colours are selected from a set of 64 possible colours – you can modify the ROM values in the IceStudio project to choose different ones.

converter IC, but this could be remapped to an external I/O pin for interfacing with a microcontroller such as an Arduino board or MicroMite.

Construction

As you can see from the PCB overlay diagram in Fig.2, there are few components on the board so it shouldn't take long to build. The board is coded 02103191, measures 49.5 × 32mm, and is available from the *PE PCB Service*.

Start by fitting the two 68Ω resistors; these are closest to CON2. Bend the legs at right angles, put through the holes and splay the legs to hold in place. Solder and trim the leads just above the solder fillet on the reverse of the board. Fit the 560Ω and 1.1kΩ resistors using a similar procedure.

Now mount the VGA socket next, ensuring it is properly seated and flush with the PCB. Solder the larger mechanical pins, turning up your soldering iron temperature if necessary.

Do ensure you solder the fine pins of the signal lines carefully to avoid bridging adjacent pins. You may find it easier to work with the centre row of pins first, and check that they are soldered and tidy before accessing the outer rows, which have more surrounding space to work with.

Finally, fit the 2 × 6 pin header. This sits underneath the PCB, on the opposite side to the other components, and is soldered from the top.

Avoid excessive heat, as this may melt the plastic shroud, putting the pins out of alignment.

Check that there are no solder bridges or short circuits, and plug the board into the PMOD header of the iCEstick. The VGA socket faces away from the USB plug of the iCEstick.

Plug a VGA cable from the VGA socket to a monitor or television.

Building and uploading the code

With the *iCEstick VGA Terminal.ice* file open in IceStudio, select the iCEstick from the Select → Board menu. To synthesise the design, click Tools → Build, and when the green 'Build done' message appears, click Tools → Upload. The keyboard shortcuts for these commands are Ctrl-B and Ctrl-U respectively.

Now connect a VGA monitor and check to see if you have a display, similar to that shown in Screen2. If you have a terminal program installed, such as TeraTerm, PuTTY or even the Arduino IDE, figure out which serial port the iCEstick is using and open a connection to it at 9600 baud with eight bits, no parity (8-N-1).

Type into the terminal, and you should see text appear on the screen. If the Enter key generates a CR/LF pair in your terminal program, pressing Enter should cause subsequent text to appear at the start of the next line. Assuming your terminal program supports control codes (which most do, except for the Arduino IDE), you can change the colours by using control key combinations.

ASCII control codes 1-26 correspond to pressing Ctrl and one of the letters A-Z on the keyboard; as A is the first letter of the alphabet, Ctrl-A sends control code 1. Press Ctrl-N or Ctrl-O to switch between setting the foreground or background colour, and press Ctrl-P through to Ctrl-Z to change that colour.

The five remaining codes between 27 and 31 map to a combination of Ctrl plus another key, those keys being: [, \,], ^ and _, respectively.

You can now use the iCEstick VGA Terminal as-is, or you may wish to experiment further to see what is possible with IceStudio.

Debugging the project

While the block-and-wire methodology of creating a design does not leave much opportunity for errors, manually entered code blocks certainly could be erroneous, and thus can cause a build error. In this case, you will see a red bar appear instead of 'Build done' after attempting a build.

It's possible to view the entire Verilog file that is generated during the build process. IceStudio converts the graphical design into a text-based (Verilog) HDL file, then builds that into the binary bitstream. That's an intensive process which involves figuring out which FPGA resources can be used to create the required logic and how they should ideally be interconnected, so it can take some time.

To view the generated Verilog, click on the View → Command Output menu option and open the folder shown in Screen3. In this folder, there is a **main.v** file, which is the Verilog code that IceStudio has generated.

If you do get a build error, scroll towards the bottom of the Command Output window and you should see an error message indicating the line number on which the error occurred (and the nature of the error). This, in combination with the generated Verilog, should help lead you to the source of the error.

It's a good idea to open **main.v** in a text editor which displays line numbers. When building the project, you may also see some warnings; most warnings can safely be ignored.

Verilog code blocks

Now that you know how to debug the code, you may wish to dabble with the Verilog inside the code blocks in this project. Here are some tips to get you started; but don't think this is the complete book on Verilog coding! Like the C language, all statements end with a semi-colon.

Some lines in the Verilog code are direct assignments, such as the following used to generate the HSYNC signal. These generate simple digital logic:

```
assign out = ((count < stop) &&
              (count >= start)) ? 1 : 0;
```

Here, the ternary operator (? :) assigns the 'out' register the value of 1 (high) if the value of 'count' is less than 'stop' and equal to or greater than 'start'. Otherwise, 'out' is assigned the value 0 (low).



The VGA Adaptor simply plugs into the matching socket on the iCEstick PCB, while the socket at left connects to the VGA screen/monitor.



This could pass for valid C code, apart from the ‘assign’ keyword, but it should be remembered that we are synthesising hardware in the form of logic gates rather than compiling machine code.

At a few places in this project, we want to increment a counter based on an input, for example:

```
reg [9:0] counter = 0;
always @(posedge clk)
begin
    counter <= (counter ==
div - 1) ? 0 : counter + 1;
    clkout <= (counter <
div/2) ? 1 : 0;
end
```

This code is in the block that divides the pixel clock down to a line clock. The first line specifies that ‘counter’ is a 10-bit register, and is set to zero on power-up.

The second line indicates that the following sequence will only occur on the positive edge of the `clk` signal. The resulting synthesis will use flip-flops to retain the state of the registers between `clk` pulses.

The `begin/end` statements are used to group the two following lines so that they both occur inside the `always` block.

Here, `counter` is incremented (ie, its value is increased by one), unless it has reached one less than the value of `div`, in which case it is reset to zero.

Thus, `counter` counts from zero to `div-1`, which gives us our horizontal pixel position in the `counter` register.

The `clkout` register is set to one while `counter` is in the bottom half of its cycle (less than `div/2`), and zero when it is in the top half, thus dividing the incoming `clk` signal by the ratio of `div`.

This `clkout` signal is fed into another similar code block, so that every time the horizontal counter reaches zero, the vertical counter is incremented. This is how our raster is generated.

You might note that these registers are loaded with a `<=` symbol instead of a `=`.

The `<=` means that they are non-blocking assignments, so they are considered to occur simultaneously.

If a specific order of assignment is needed, then the `=` blocking assignment operator can be used to enforce

this, particularly if the result of one expression depends on the result of a previous expression.

The memory block demonstrates a few other features of Verilog. Using this specific form of assignment is needed to enforce the use of block RAM, as mentioned earlier:

```
reg [7:0] mem [511:0];

always @(posedge wclk) begin
    if (write_en)
        mem[waddr] <= din;
end

always @(posedge rclk) begin
    dout <= mem[raddr];
end

initial begin
    if (MEM)
        $readmemh (MEM, mem);
end
```

The first line defines an internal register file `mem`, which has 512 (511-0) eight-bit (7-0) elements, effectively, an array. The first `always` block is responsible for writing to the memory, where the 8-bit value `din` is stored at position `waddr` in `mem` on the positive edge of `wclk`, but only if `write_en` is high (one).

The second `always` block performs a read, loading the value of the memory (`mem`) at `raddr` to the `dout` register on the rising edge of `rclk`. Block RAM is always synchronous (requiring a clock) on the iCEstick’s iCE40HX-1k.

Changing the baud rate

We suggested earlier that some of the features such as baud rate, graphics and colours can easily be modified. The baud rate is controlled by a single value within the UART block.

Around line 26 inside the UART block is the definition of the `CLOCK_DIVIDE` parameter.

You can select 115200 baud by commenting (adding `//` to the start of) this line:

```
parameter CLOCK_DIVIDE = 312;
```

and removing the `//` from the start of:

```
//parameter CLOCK_DIVIDE = 26;
```

Note that the `CLOCK_DIVIDE` value is determined by dividing 12,000,000 by four times the baud rate (or 3,000,000 divided by the baud rate) and choosing the next lower integer.

Choosing the next lower integer means the baud rate is slightly faster than desired, but this will handle receiving a steady stream of characters better than a slightly slower baud rate.

Changing the font

The font ROM consists of groups of eight 8-bit hexadecimal values inside the three FONT blocks. The top-most block encodes ASCII codes 0-63, the second 64-127, and the third 128-191.

The most-significant bit is at left, and the least-significant bit at right, with the data in rows in order from top to bottom.

Refer to Fig.3, which shows how the letter ‘A’ is encoded (it is found at addresses 0x08 to 0x0F near the top of the second font ROM block). The whole font is shown in Screen4.

Changing the colours

The colours are formed by a similar bit-map, with 16 6-bit hexadecimal entries.

The two most-significant bits are for the blue level, the middle two bits for the green, and the bottom two bits for red.

Thus 0x00 is black and 0x3F is white, as per the first two entries, with the third entry 0x03 being red.

Because the foreground and background colours are stored in separate ROMs, you could provide different colour maps for each, but that might be a bit confusing to use.

I/O pin assignments

Finally, you may wish to map the serial data to a different pin, so you aren’t using the USB/serial converter. This is done by changing the pin connected to the ‘rx’ input of the UART module, as shown in Screen5.

We recommend using the ‘TR’ or ‘BR’ groups of pins for I/O; these are the rows of solder pads along the edges of the board. (Refer to the iCEstick manual to check which pin is which.)

Take care as the pins are only rated for 3.3V I/O levels, so directly connecting a 5V microcontroller is not recommended, and a level converter or voltage divider should definitely be used in that case.

Reproduced by arrangement with
SILICON CHIP magazine 2020.
www.siliconchip.com.au

STORE YOUR BACK ISSUES ON CD-ROMS

- VOL 1 BACK ISSUES** – January 1999 to June 1999
Plus bonus material from Nov and Dec 1998
- VOL 2 BACK ISSUES** – July 1999 to December 1999
- VOL 3 BACK ISSUES** – January 2000 to June 2000
- VOL 4 BACK ISSUES** – July 2000 to December 2000
- VOL 5 BACK ISSUES** – January 2001 to June 2001
- VOL 6 BACK ISSUES** – July 2001 to December 2001
- VOL 7 BACK ISSUES** – January 2002 to June 2002
- VOL 8 BACK ISSUES** – July 2002 to December 2002
- VOL 9 BACK ISSUES** – January 2003 to June 2003
- VOL 10 BACK ISSUES** – July 2003 to December 2003
- VOL 11 BACK ISSUES** – January 2004 to June 2004
- VOL 12 BACK ISSUES** – July 2004 to December 2004
- VOL 13 BACK ISSUES** – January 2005 to June 2005
- VOL 14 BACK ISSUES** – July 2005 to December 2005
- VOL 15 BACK ISSUES** – January 2006 to June 2006
- VOL 16 BACK ISSUES** – July 2006 to December 2006
- VOL 17 BACK ISSUES** – January 2007 to June 2007
- VOL 18 BACK ISSUES** – July 2007 to December 2007
- VOL 19 BACK ISSUES** – January 2008 to June 2008
- VOL 20 BACK ISSUES** – July 2008 to December 2008
- VOL 21 BACK ISSUES** – January 2009 to June 2009
- VOL 22 BACK ISSUES** – July 2009 to December 2009
- VOL 23 BACK ISSUES** – January 2010 to June 2010

FIVE-YEAR DVD/CD-ROMs

- No.1** – Jan 03 to Dec 07
- No.2** – Jan 04 to Dec 08
- No.3** – Jan 05 to Dec 09
- No.4** – Jan 06 to Dec 10
- No.5** – Jan 07 to Dec 11
- No.6** – Jan 08 to Dec 12
- No.7** – Jan 09 to Dec 13
- No.8** – Jan 10 to Dec 14
- No.9** – Jan 11 to Dec 15
- No.10** – Jan 12 to Dec 16
- No.11** – Jan 13 to Dec 17
- No.12** – Jan 14 to Dec 18 – **NEW!**

ONLY £16.45 each
Five years just £29.95
including VAT and p&p

- VOL 24 BACK ISSUES** – July 2010 to December 2010
- VOL 25 BACK ISSUES** – January 2011 to June 2011
- VOL 26 BACK ISSUES** – July 2011 to December 2011
- VOL 27 BACK ISSUES** – January 2012 to June 2012
- VOL 28 BACK ISSUES** – July 2012 to December 2012
- VOL 29 BACK ISSUES** – January 2013 to June 2013
- VOL 30 BACK ISSUES** – July 2013 to December 2013
- VOL 31 BACK ISSUES** – January 2014 to June 2014
- VOL 32 BACK ISSUES** – July 2014 to December 2014
- VOL 33 BACK ISSUES** – January 2015 to June 2015
- VOL 34 BACK ISSUES** – July 2015 to December 2015
- VOL 35 BACK ISSUES** – January 2016 to June 2016
- VOL 36 BACK ISSUES** – July 2016 to December 2016
- VOL 37 BACK ISSUES** – January 2017 to June 2017
- VOL 38 BACK ISSUES** – July 2017 to December 2017
- VOL 39 BACK ISSUES** – January 2018 to June 2018
- VOL 40 BACK ISSUES** – July 2018 to December 2018
- VOL 41 BACK ISSUES** – January 2019 to June 2019

15 YEARS OF EPE!

AMAZING BUNDLE OFFER

- No.1 – Jan 03 to Dec 07**
PLUS
No.6 – Jan 08 to Dec 12
PLUS
No.11 – Jan 13 to Dec 17

ALL FOR JUST
£39.95

All DVD/CD-ROMs are suitable for any PC with a DVD/CD-ROM drive.
They require Adobe Acrobat Reader (free from: www.adobe.com/acrobat)

ORDER YOUR CD-ROMs TODAY!

JUST CALL 01202 880299 OR VISIT www.electronpublishing.com

Ultra-low-distortion Preamplifier with Tone Controls

Part 2



by John Clarke

Last month, we introduced our state-of-the-art stereo Preamplifier. Along with almost unmeasurable noise and distortion – typically 0.0003% THD+N! – it sports remote volume control, input selection and muting, plus bass and treble adjustment knobs on the front panel. Now let's build the input selection boards and power supply.

The circuits of the optional input selector board and front-panel pushbutton board were shown in Figs.8 and Fig.9 last month.

We also listed the parts required to build those two boards in that article. Fig.10 and Fig.11 show the PCB overlay diagrams for these two boards, so you can see how those parts are fitted.

By the way, you don't have to build either of these boards if you don't need the ability to select between more than one set of stereo inputs. In that case, you would connect the chassis-mounted input sockets directly to CON1 and CON3 on the main *Preamplifier* board.

Constructors – please read note in the April 2020 issue Parts List before purchasing components.

If you do want the *Input Selector* but only need the remote control feature, and don't want front panel pushbuttons/input indicators, you could build the input selector board (Fig.10) but not the front panel push-button board (Fig.11).

You can then use the remote control to select between the three inputs, although it won't show which is selected – you will have to remember the last selection you made.

Incidentally, we haven't listed all the features and specifications again – refer to the April issue for these and performance graphs. (We think you'll agree, it's outstanding!)

Input selector construction

The *Input Selector* board is easy to assemble. It's built on a double-sided

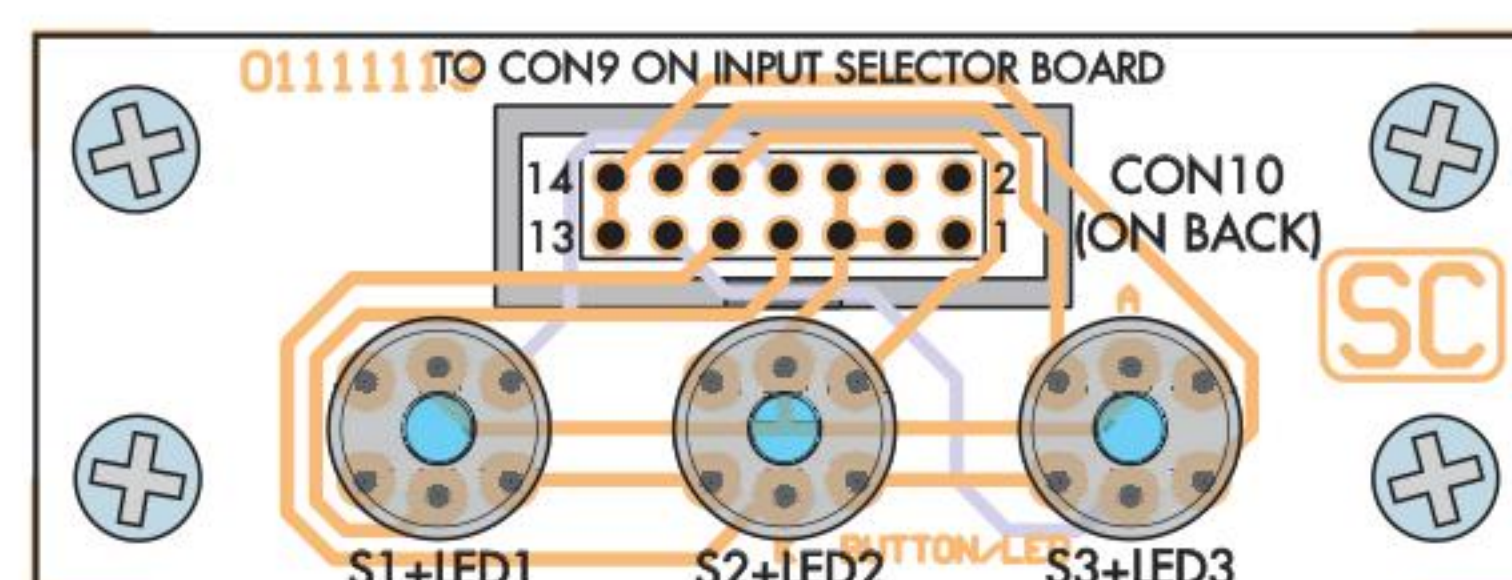
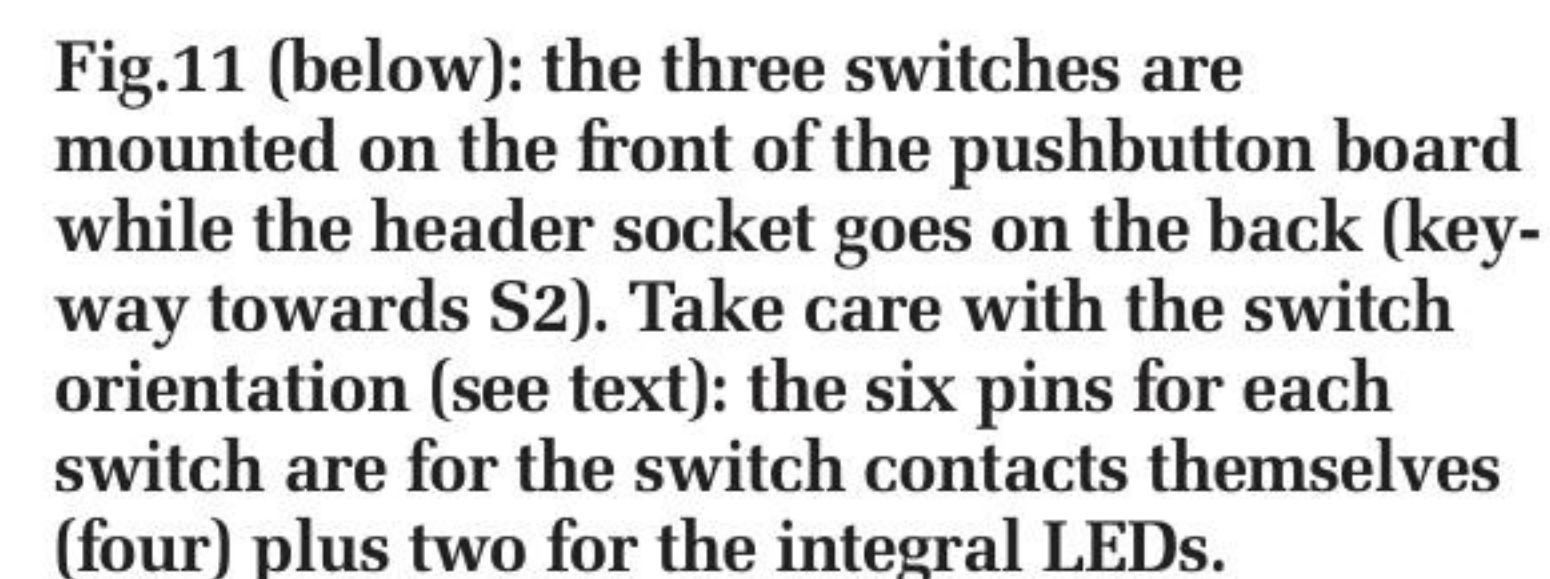
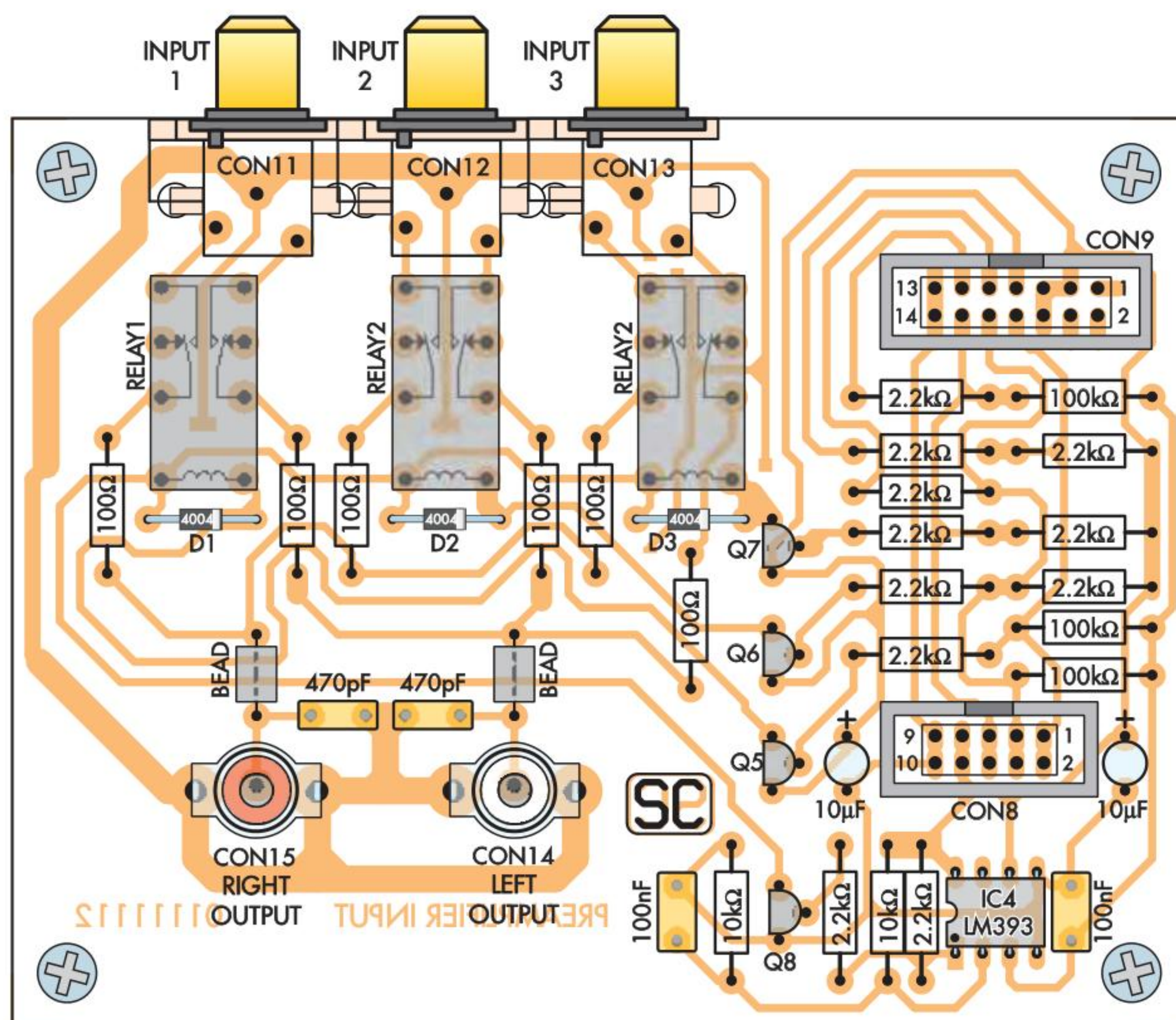
PCB, coded 01111112, measuring 110 × 85mm and available from the *PE PCB Service*).

Start by fitting the resistors where shown. Remember to always check resistor values with a DMM set to measure resistance to make sure they're going in the right places.

Follow with diodes D1-D3, ensuring that their cathode stripes face as shown, then feed some resistor lead offcuts through the ferrite beads and solder them in place.

Features

- Bass and treble controls
- Motorised volume control
- Infrared remote or manual control
- Relay input switching and isolation
- Suits practically any amplifier module.



We recommend you solder IC4 directly to the board, although you can use a socket if you really want to. Either way, make sure its pin 1 dot/notch faces to the left, as shown. Fit the MKT/MKP/ceramic capacitors next.

We explained in detail last month why there are three different options for the 470pF capacitors, and that if you use ceramics, they must be NP0/C0G types for good performance.

We used MKTs on our prototype. Mount them, plus the two 100nF MKTs now.

Next, solder the four transistors, noting that Q5-Q7 are BC327s, while Q8 is a BC337. The two electrolytics can then go in, with the longer positive leads through the holes marked '+', followed by the 10-way and 14-way header sockets, CON8 and CON9.

These sockets must be installed with their slotted key-ways towards the top. Finally, complete the

assembly by installing the relays, the three stereo RCA input sockets and the two vertical RCA output sockets.

Note the left and right labelling for the output sockets – this is not a mistake and arranging them this way gives the optimum layout for the PCB.

Front panel pushbutton board assembly

There just four parts on the pushbutton board – the three pushbutton switches on one side and the 14-way IDC header socket on the other (see Fig.11 above). The board is coded 01111113, measures 66 × 25mm and is available from the *PE PCB Service*.

The three pushbuttons can go on first, but note that they must be installed the right way around.

These have 'kinked' pins at each corner plus two straight pins for the integral blue LED. The anode pin is the longer of the two and this must go in the hole marked 'A' on the PCB (towards the header).

Once the pins are in, push the buttons all the way down so that they sit flush against the PCB before soldering their leads.

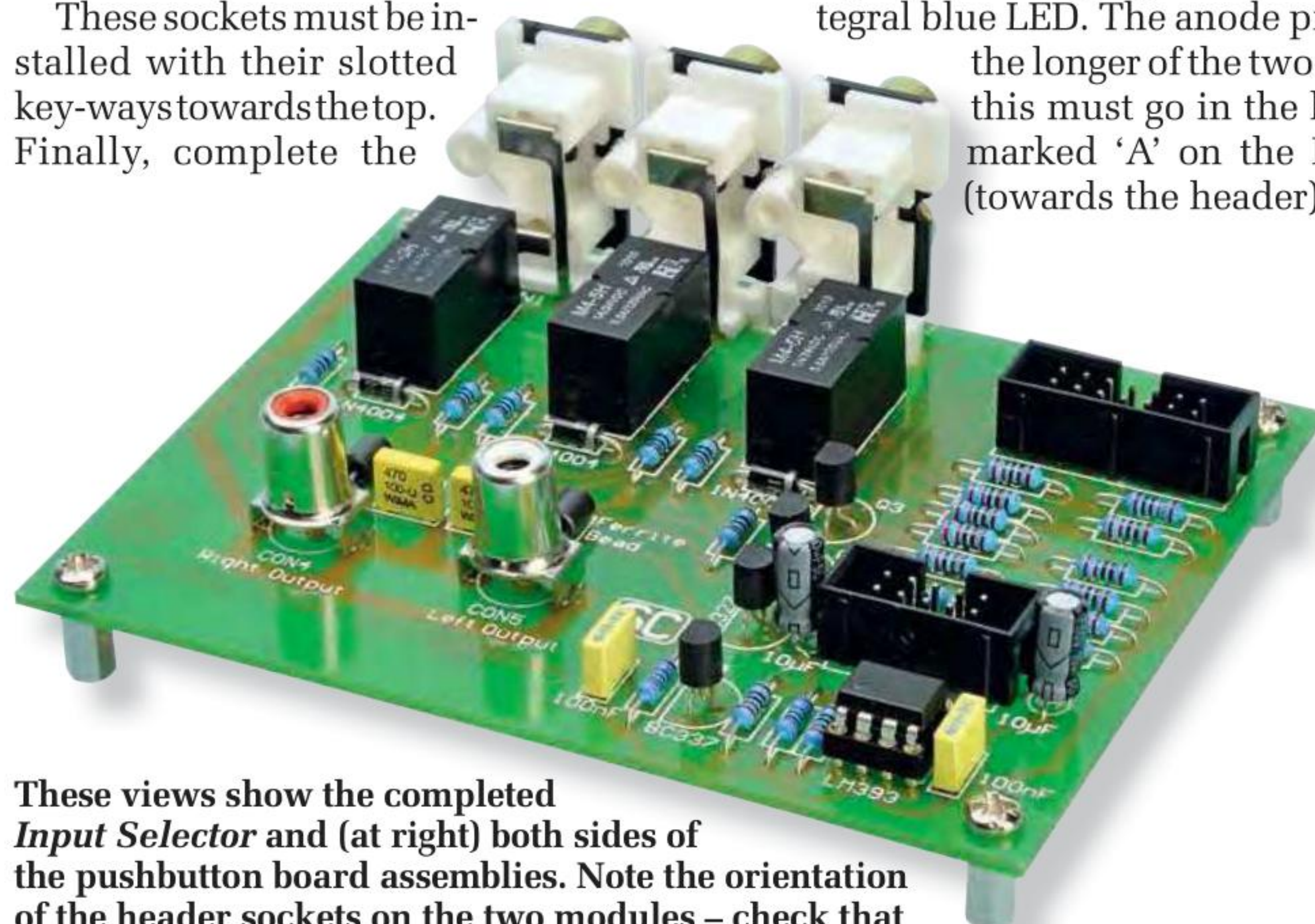
The IDC header socket can then be installed on the other side of the board, with its key-way notch towards the bottom.

Choice of power supply

If you're building this *Preamplifier* as part of a full amplifier, chances are you already have a suitable power supply producing the required $\pm 15\text{V}$ DC rails. Otherwise, we mentioned a few suitable power supply designs last month – see the box at the end of the article.

If you're building a standalone *Preamplifier*, or building the *Preamplifier* into an amplifier which already has a power supply but doesn't have $\pm 15\text{V}$ DC rails then you could use the the *4-Output Universal Voltage Regulator* from our May 2016 issue. The parts are easy to source and the PCB (code 18105151) is available from the *PE PCB Service*.

However, there are two other options. You could build a simple low-power *Universal Regulator*. The parts are easy to source and we can sell you the board (code 18103111). You could choose



this supply for the same reasons as the 4-Output model described above.

However, if you are also building a power amplifier from scratch, then it is worth considering the *Ultra-LD Power Supply* board. It is available as a kit (code K5168) from Altronics, or you can buy its PCB (code 01109111) from the *PE PCB Service* and source your own parts.

As noted above, the the 4-Output *Universal Voltage Regulator* was covered in our May 2016 issue, so we'll only explain building the other two supplies here.

Building the Universal Regulator

Fig.12 shows the circuit of the *Universal Regulator* while Fig.13 is the PCB overlay.

You can power it from a 30V centre-tapped transformer secondary (15-0-15V) or a single 15V winding. The centre-tapped option is better if you can swing it, since it results in a lower ripple at the regulator inputs.

The transformer's AC output is rectified by a diode bridge (D1-D4) and filtered by a pair of 2200 μ F capacitors.

It's then regulated to +15V by REG1 and -15V by REG2. These regulated rails are available from terminal block CON2, which is wired to the *Preamplifier*.

Its built on a PCB measuring 71 $\times$ 35.5mm; see opposite for the list of parts you'll need.

Start assembly by fitting the the two resistors and then the six diodes (with the polarity shown in Fig.13).

Next, mount the LEDs with the longer (anode) leads towards the bottom of the board. Follow with the two MKT capacitors.

You can then fit the two 3-way terminal blocks, with the wire entry holes facing the nearest edge of the board.

The *Universal Regulator* power supply board can handle a wide range of inputs and outputs. With a 15-0-15V AC transformer you will get a regulated +15, 0V and -15V DC supply, perfect for the *Ultra Low Noise Preamplifier* (and many other projects!).

Now solder REG1 and REG2 with the tabs towards the board edge as shown, taking care not to get the two mixed up. Finally, solder the four capacitors in place, ensuring that their longer (positive) leads go into the pads marked with a '+' symbol.

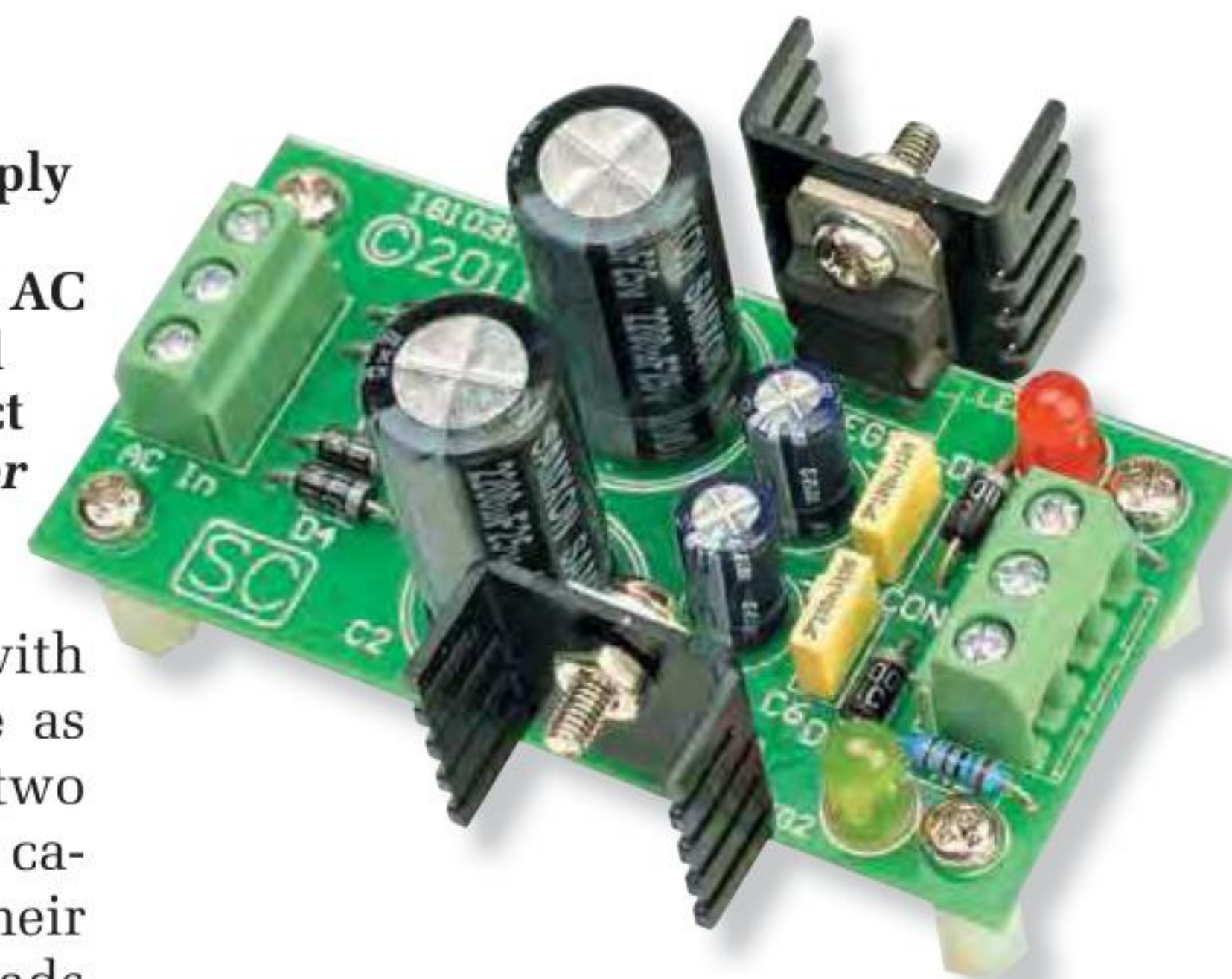
The photo above shows two flag heatsinks (and they are mentioned in the parts list). It won't hurt to fit these, but if you're only going to be powering the *Preamplifier* and your transformer secondary voltage is the recommended value, they should not be necessary since the *Preamplifier* doesn't draw a lot of current.

Building the Ultra-LD Power Supply

The circuit of the *Ultra-LD Power Supply* is shown in Fig.14. The bottom section is similar to the *Universal Regulator* described above and operates in the same manner. A chassis-mount bridge rectifier is used for the high-voltage AC secondaries of the power transformer, which are shown as 40-0-40V here, but lower voltages can be used with this board too.

The resulting DC rails are then filtered by three 4700 μ F capacitors each and made available at CON1 and CON2, to be fed to the amplifier modules.

Fig.15 is the PCB overlay for this supply. The two wire links should not be necessary as our boards are double-sided and have copper strips on the



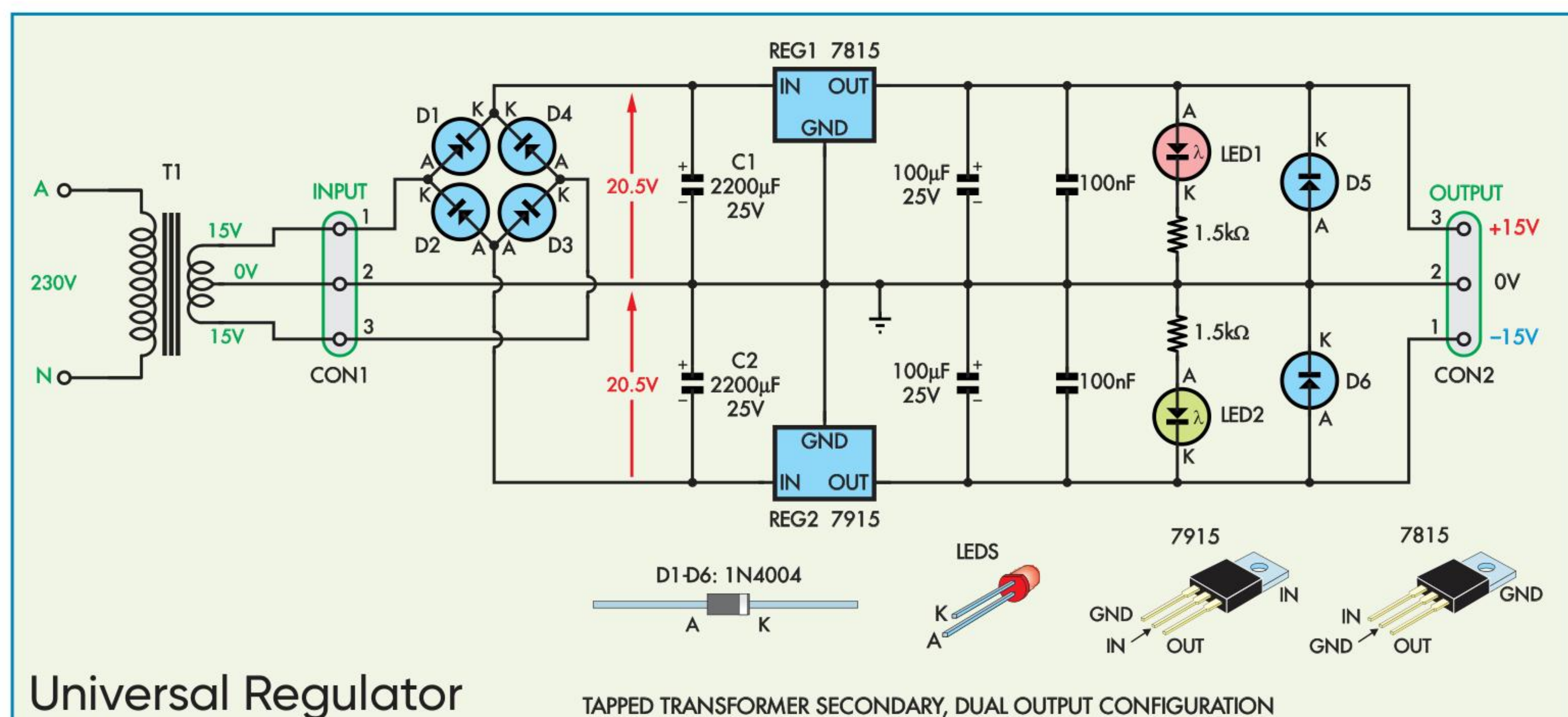
top layer connecting these points, but if you DIY etch a single-sided board, you will need to fit the two links using 1mm-diameter tinned or enamelled copper wire.

Next, mount the diodes with the orientation shown, then the LEDs, with the longer (anode) leads towards the top of the board. You can then bend the regulator leads to fit the hole pattern on the PCB and attach their tabs to the board securely using M3 machine screws and nuts.

Once you've checked that they are straight, solder and trim the leads.

The terminal blocks go in next. Dovetail CON4 with CON5 and CON3 with CON6 before soldering them in place, with the wire entry holes facing towards the nearest edge of the board. Then you can mount the two 5W resistors, with their bodies a few millimetres above the PCB surface to allow cooling air to circulate.

Next, install the spade connectors. If using the vertical type with two pins, push these into the board and solder them in place – you will need a hot iron to do this. If using the chassis-mounting



Universal Regulator

Fig.12: the *Universal Regulator* circuit generates ± 15 V rails. Diodes D1-D4 form a bridge rectifier, while capacitors C1 and C2 filter the rectified AC. Regulators REG1 and REG2 provide a steady output voltage, while LED1 and LED2 indicate operation. You can also use a transformer with a single secondary (or a plugpack) connected between pins 1 and 2, or 2 and 3 of CON1.

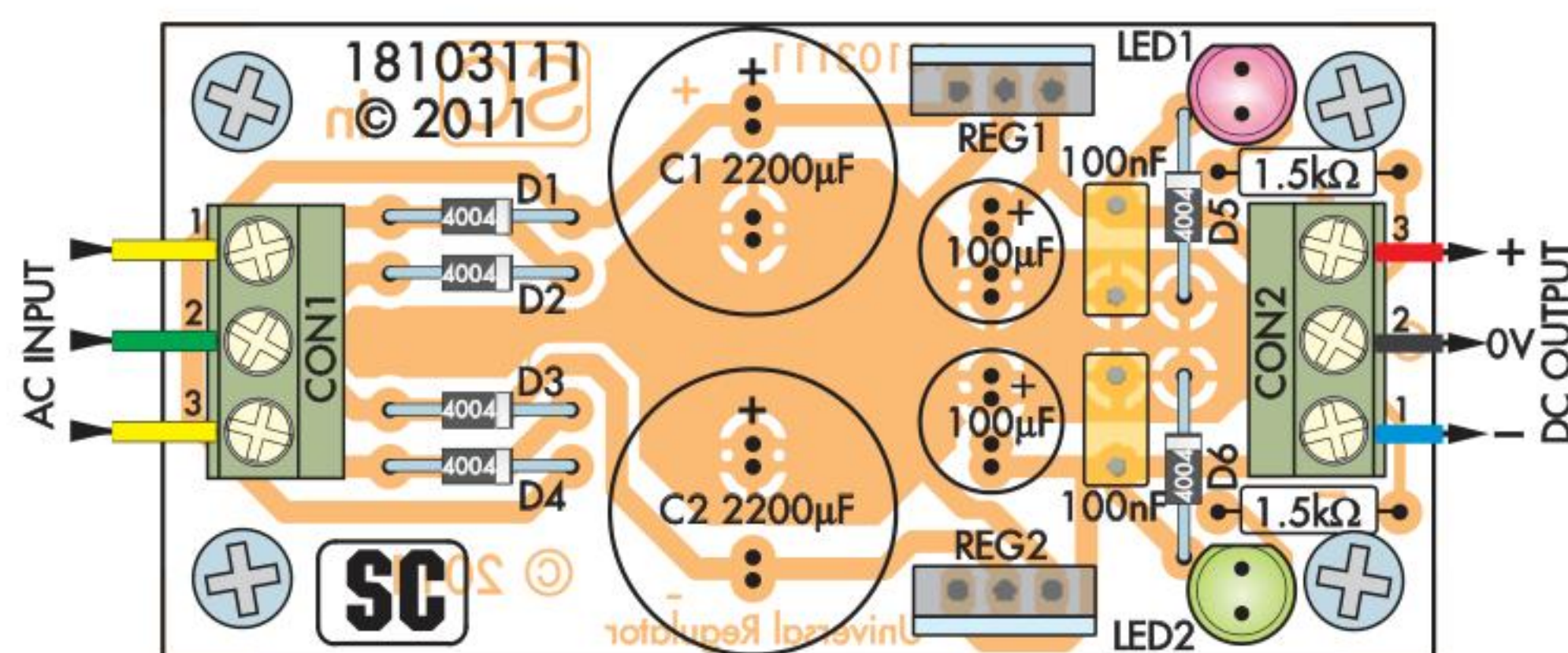


Fig.13: this PCB overlay corresponds with the circuit of Fig.12. You could fit flag heatsinks to REG1 and REG2 but they are not strictly necessary for use with the *Preamplifier*, as it doesn't draw a lot of current.

type, attach them to the board using the specified M4 machine screws and nuts, as shown in Fig.16.

Now all that's left is to solder the small electrolytics capacitors in place, followed by the large ones. In both cases, the longer (positive) leads must go into the pads marked with a '+' on the PCB.

Initial checks

Before installing the three ICs on the preamp board, it's a good idea to check the supply voltages. You will need to wire up a transformer to your power supply, then connect the power supply's +15V, 0V and -15V outputs to the relevant inputs on the main preamplifier PCB.

It's safer to use a 15VAC plugpack for testing if you don't already have the transformer and power supply installed in an *earthed* metal chassis. Just connect one wire from the plugpack output to either of the low-voltage AC input terminals on the power supply board, and the other wire to the centre tap transformer connection point.

Plug the plugpack into a mains socket and switch on. Now check the voltages on pins 8 and 4 of the

four 8-pin IC sockets (IC1-IC4) on the preamp board; ie, between each of these pins and the 0V (centre) terminal of CON6. You should get readings of +15V and -15V respectively.

Similarly, check the voltage on pin 14 of IC5's socket. It should be between +4.8V and +5.2V.

If these voltages are correct, switch off and install the ICs. Note that IC1-IC4 face one way, while microcontroller IC5 faces the other way.

Remote control/switch testing

The remote control functions can now be tested using a suitable universal remote, eg, Altronics A1012. As stated earlier, the default device mode programmed into the micro is TV, but if this conflicts with other gear you can choose SAT1 or SAT2 as the device instead.

Whichever mode is chosen, you must also program the correct code into the remote (see panel below).

Note that if you don't have a split rail power supply ready yet, you can still check the remote control functions by using a single 9-15V DC supply connected between the +15V and 0V terminals of CON6 (watch the polarity).

Selecting The Mode and Programming The Remote

As stated in the text, it's necessary to program the universal remote control correctly. By default, the microcontroller's RC5 code is set to TV but SAT1 or SAT2 can also be selected. Just press and hold button S1 on the pushbutton board during power-up for SAT1 or button S2 for SAT2. Pressing S3 at power-up reverts to TV mode.

Once you've chosen the mode or 'device', the correct code must be programmed into the remote. This involves selecting TV, SAT1 or SAT2 on the remote (to agree with the microcontroller set-up) and then programming in a three or 4-digit number for a Philips device. That's because most Philips devices (but not all) use the RC5 code standard that's expected by the Preamplifier.

Most universal remote controls can be used, including the model shown above, the Altronics A1012 and the Jaycar AR1955 or AR1954. For the Altronics A1012, use a code of 023 or 089 for TV mode, 242 for SAT1 or 245 for SAT2.

Similarly, for the Jaycar remotes, use code 1506 for TV, 0200 for SAT1 or 1100 for SAT2.

In the case of other universal remotes, it's just a matter of testing the various codes until you find one that works. There are usually no more than 15 codes (and usually fewer) listed for each Philips device, so it shouldn't take long to find the correct one.

Note that some codes may only partially work, eg, they might control the volume but not the input selection. In that case, try a different code. Also, some remotes may only work in one mode (eg, TV but not SAT).

Parts list Universal Regulator (±15V outputs)

- 1 PCB, code 18103111, 71 x 35.5mm, available from the PE PCB Service.
- 1 transformer, 230V AC primary, 15-0-15V AC or 230V AC to 15V AC plugpack to suit (see text)
- 2 3-way terminal blocks, 5.08mm pitch
- 4 tapped spacers
- 4 M3 x 6mm machine screws
- 2 TO-220 heatsinks (optional)
- 2 M3 x 10mm machine screws, nuts and shakeproof washers for heatsinks

Semiconductors

- 1 7815 +15V linear regulator
- 1 7915 -15V linear regulator
- 6 1N4004 diodes
- 1 red 5mm LED 1 green 5mm LED

Capacitors

- 2 2200µF 25V electrolytics
- 2 100µF 25V electrolytics
- 2 100nF MKT

Resistors (all 0.25W 1% metal film)

- 2 1.5kΩ

Ultra-LD amp/preamp power supply (±57V and ±15V outputs)

- 1 PCB, code 01109111, 141 x 80mm, available from the PE PCB Service.
- 1 transformer, 40-0-40V and 15-0-15V AC secondaries (see text)
- 4 3-way PCB-mount terminal blocks, 5.08mm pitch (Altronics P2035A or equivalent) (CON1-4)
- 2 2-way PCB-mount terminal blocks, 5.08mm pitch (Altronics P2034A) (CON5-6)
- 3 PCB-mount or chassis-mount spade connectors [Altronics H2094]
- 3 M4 x 10mm screws, nuts, flat washers and shakeproof washers (if using chassis-mount spade connectors)
- 4 M3 x 9mm tapped nylon spacers
- 6 M3 x 6mm machine screws
- 2 M3 shakeproof washers and nuts
- 150mm 0.7mm dia. tinned copper wire

Semiconductors

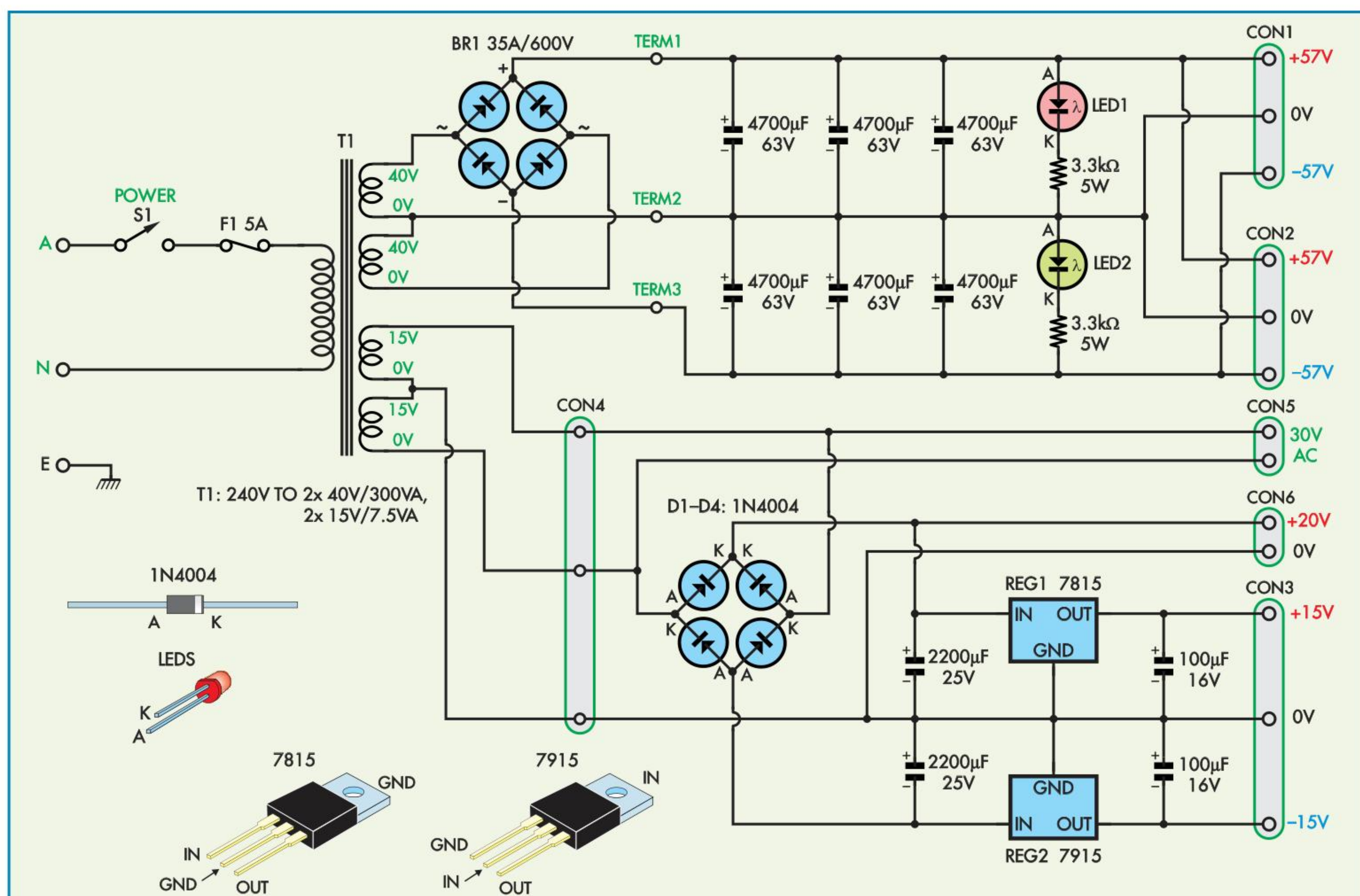
- 1 35A 400W chassis-mounting bridge rectifier (BR1)
- 1 7815 1A 15V positive linear regulator (REG1)
- 1 7915 1A 15V negative linear regulator (REG2)
- 4 1N4004 1A diodes (D1-D4)
- 1 5mm green LED (LED1)
- 1 5mm red LED (LED2)

Capacitors

- 6 4700µF 63V electrolytic
- 2 2200µF 25V electrolytic
- 2 220µF 16V electrolytic

Resistors

- 2 3.3kΩ 5W



Power amplifier and preamplifier power supply

Fig.14: the *Ultra-LD Power Supply* is based on a toroidal transformer (T1) with two 40V windings and two 15V windings, but you could use two separate transformers if necessary. You can use a transformer with lower voltage main secondary windings (ie, less than 40V) to achieve a lower amplifier supply voltage, without making any changes to the board.

As before, check the voltage on pin 14 of IC5's socket (it must be between +4.8V and +5.2V), then switch off and install IC5 (pin 1 towards IRD1). Also, insert the jumper link for LK3 to enable the mute return function.

Now connect the three boards using the ribbon cable assemblies. The connectors are all keyed, so as long as you

plug the 10-wire cable into the 10-pin sockets and the 14-wire cable into the 14-pin sockets, everything should be connected properly.

Next, rotate VR2 fully anticlockwise and use the remote to check the various functions. First, check that the inputs can be selected using the 1, 2 and 3 buttons on the remote and the S1-S3

buttons on the pushbutton board. Each time a button is pressed, you should hear a 'click' as its relay switches on and the blue LED in the corresponding switch button should light.

Also, the orange Acknowledge (ACK) LED should flash each time you press a button on the remote. If the ACK LED doesn't flash, make sure the code programmed into the remote matches the device mode (ie, TV, SAT1 or SAT2). The

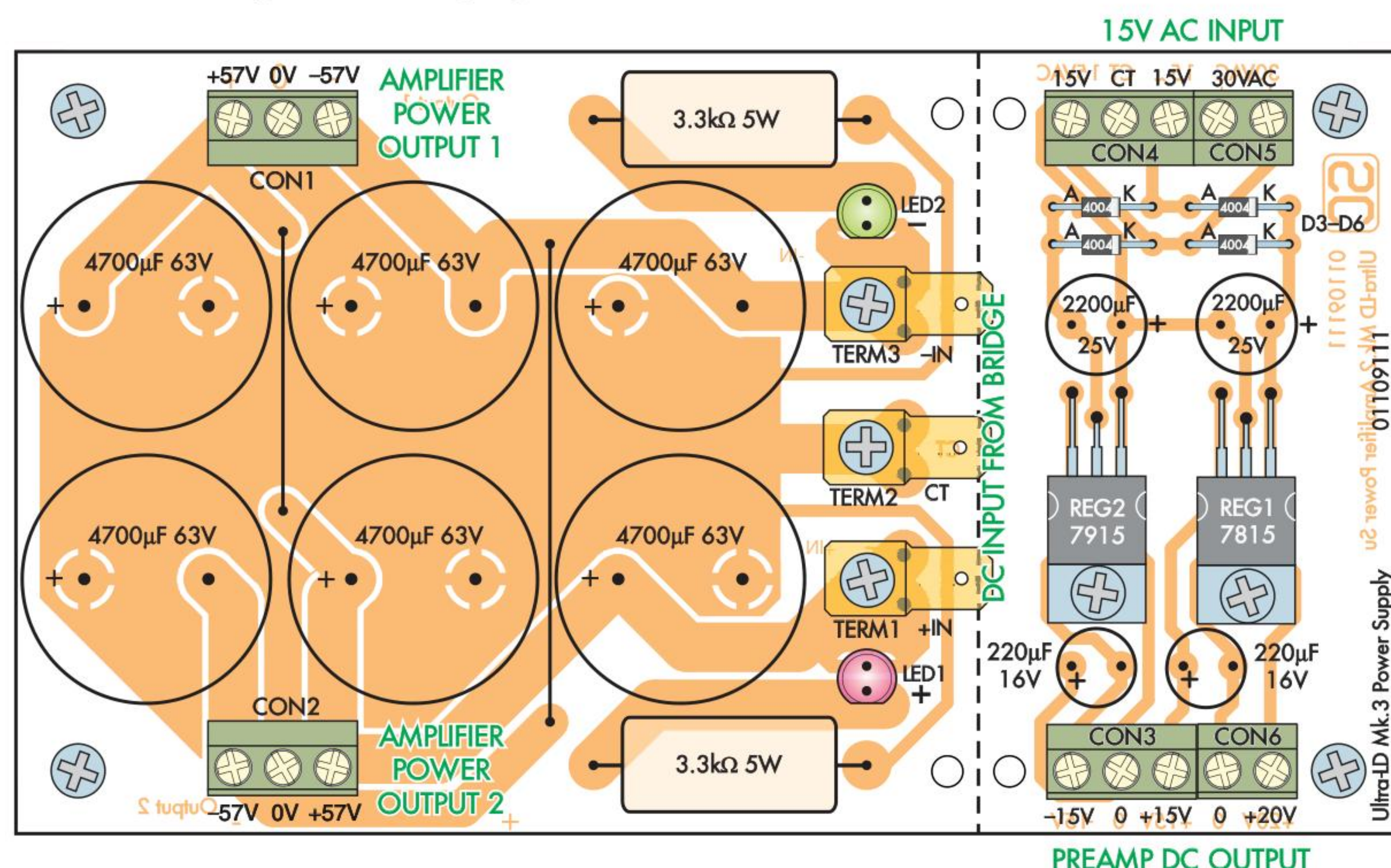


Fig.15: install the parts on the *Ultra-LD Power Supply* board as shown here, taking care to ensure that all the electrolytic capacitors are mounted with the correct polarity. Be sure also to use the correct regulator at each location. The two LEDs indicate when power is applied and remain lit until the 4700µF capacitors discharge after switch-off.



The *Ultra-LD Power Supply* can handle both an amplifier and this *Preamplifier*. Be sure to watch the polarity of electrolytic capacitors, diodes, LEDs and regulators.

ACK LED won't flash at all unless the code is correct.

Now check that the volume pot turns clockwise when the Volume Up and Channel Up buttons are pressed and anti-clockwise when Volume Down and Channel Down are pressed. It should travel fairly quickly when Volume Up/Down buttons are pressed and at a slower rate when the Channel Up/Down buttons are used. If it

turns in the wrong direction, reverse the leads to the motor.

Adjusting trimpot VR2

Next, set the volume control to mid-position, set VR2 fully anti-clockwise and hit the Mute button. The pot will rotate anti-clockwise, and as soon as it hits the stops, the clutch will start to slip.

While this is happening, slowly adjust VR2 clockwise until the motor stops. Now press Volume Up to turn the potentiometer clockwise for a few seconds and press Mute again. This time, the motor should stop as soon as the pot reaches its anticlockwise limit.

A programmed time-out of 13 seconds will also stop the motor if it continues to run after Mute is activated. This means that you have to adjust VR2 within this 13s period. If the motor stops prematurely or runs for the full 13s after the limit is reached, try redoing the adjustment.

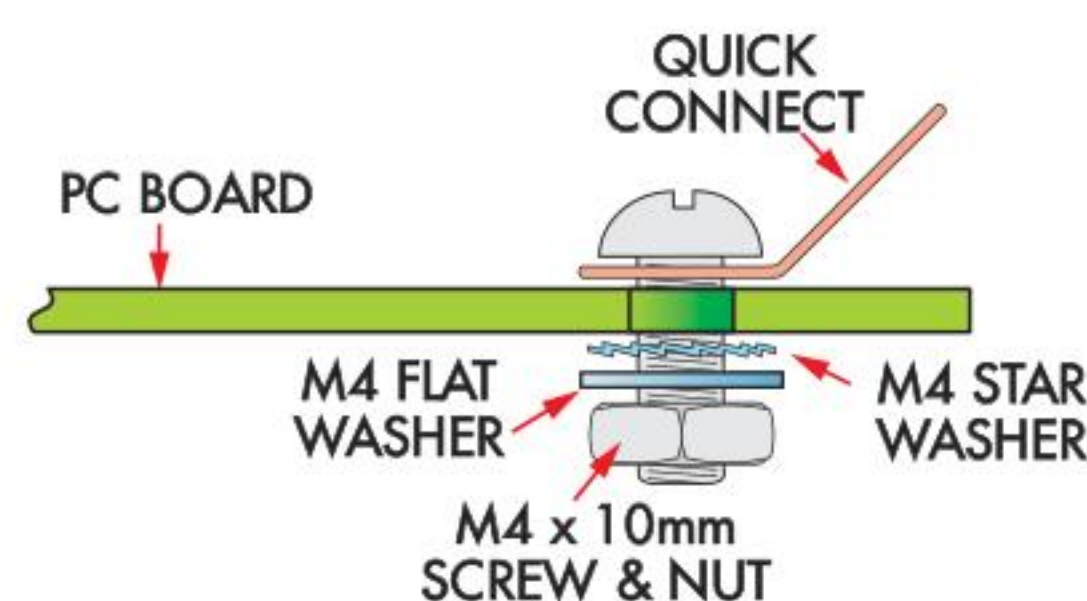


Fig.16: here's how the single-ended male spade quick connectors are secured to the power supply PCB. Vertical spade terminals with solderable pins can also be used.

Troubleshooting

If the unit fails to respond to remote control signals, check that the remote is in the correct mode (TV, SAT1 or SAT2) and has been correctly programmed.

If you're using a remote other than those listed in the panel, work through the different codes until you find one that works. Start with codes listed under the Philips brand as these are the most likely to work.

If the unit responds to the 1, 2 and 3 buttons on the remote but the button switches don't work, check that the ribbon cable to the pushbutton board has been crimped properly. Similarly, if the remote volume function works but not the remote input selection, check the cable from the *Preamplifier* board to the input selector board.

Note that the cable from the *Preamplifier* board also supplies power to the other two boards.

So it's worthwhile checking that there is 5V between pins 8 and 4 of IC4 on the *Selector* board and again check the ribbon cable if this supply rail is missing.

Audio testing

If you are using a $\pm 15V$ supply for testing, you can test the *Preamplifier* further by connecting its outputs to a stereo amplifier and feeding in audio signals from a mobile phone, tablet, iPod, CD/DVD/Blu-Ray player or just about any other source.

Depending on your device, you may need a cable with a 3.5mm stereo plug at one end and red/white RCA plugs at the other end to make the connection. These are commonly available.

Reproduced by arrangement with
SILICON CHIP magazine 2020.
www.siliconchip.com.au

Making the interconnecting cables

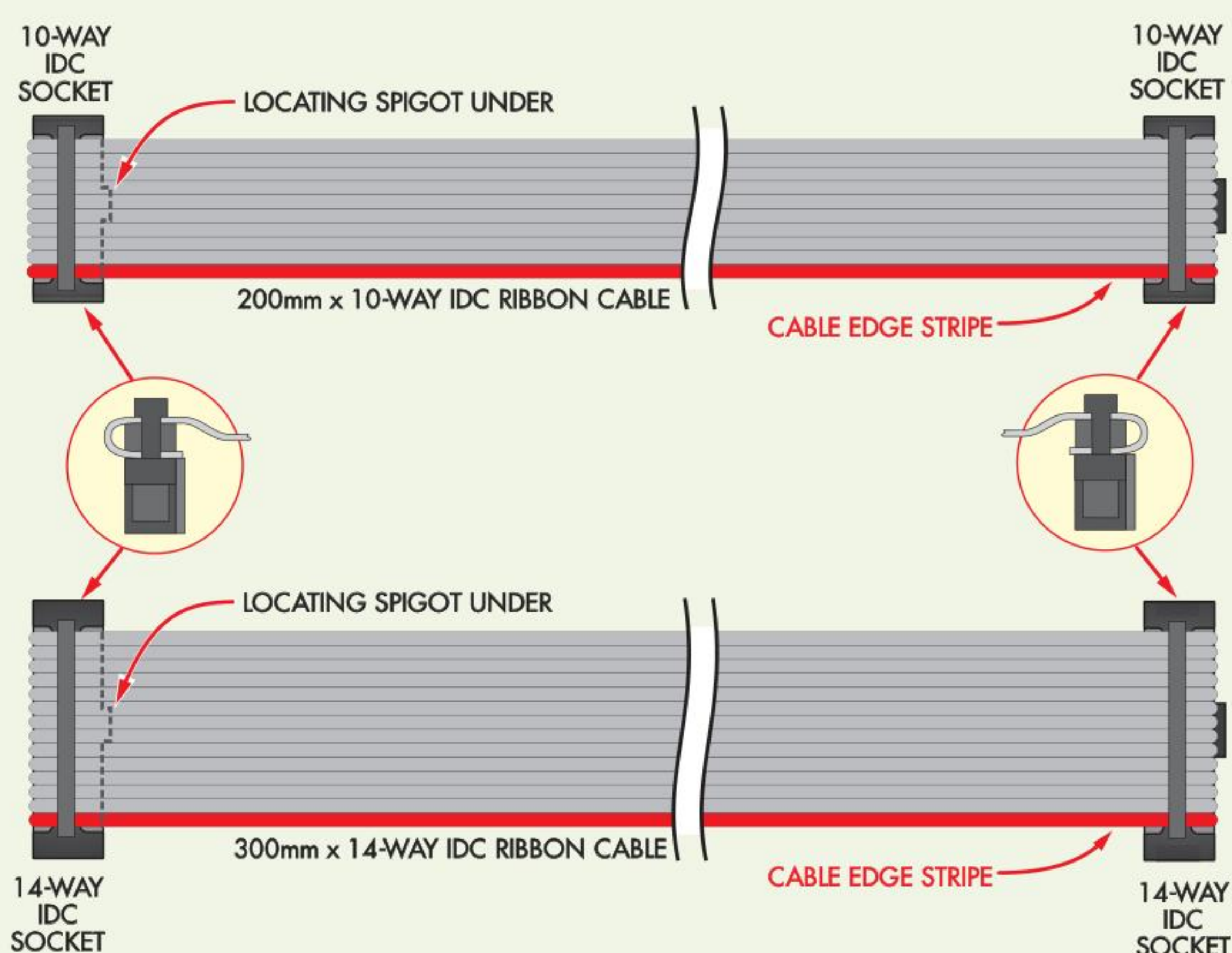
To connect the three boards, you need to make two IDC cables. These diagrams show how these cables are made.

Pin 1 on the header sockets is indicated by a small triangle in the plastic moulding and the red stripe of the cable must always go to these pins.

You can either crimp the IDC headers to the cable in a vice or use an IDC crimping tool (eg, Altronics T1540 or Jaycar TH1941).

Don't forget to fit the locking bars to the headers after crimping, to secure the cable in place.

Having completed the cables, it's a good idea to check that they have been correctly terminated. The best way to do this is to plug them into the matching sockets on the PCB assemblies and then check for continuity between the corresponding pins at either end using a multimeter.



Circuit Surgery

Regular clinic by Ian Bell

Impedance measurement and Howland current sources

In a recent post on the EEweb forum, Fariz Kurnia Sandy writes: 'I want to build a circuit for bioimpedance spectroscopy (BIS) or electrical impedance spectroscopy (EIS) using an improved Howland current source (Fig.1) for the V-to-I converter, and I want to measure the actual current injected into an object (such as tissue). Injected current is found from the formula $I = V/R_x$, where R_x is the load to convert the voltage to current. Here, the voltage is the input voltage from the source, not the voltage after the amplifying process using an op amp (assuming a perfect op amp). Of course, no op amp is perfect. For example, if the input voltage is 1V, with $R_x = 1k\Omega$, the injected current is 1mA (assuming an ideal op amp). I want to measure the actual injected current, from the actual applied voltage – what is the best way to do this?' [Edited for publication.]

Fariz's circuit is part of a system to measure impedance over a range of frequencies, so we will start with a discussion of what impedance is before looking in more detail at the Howland current source he uses, and then discussing the current measurement that Fariz's is asking about.

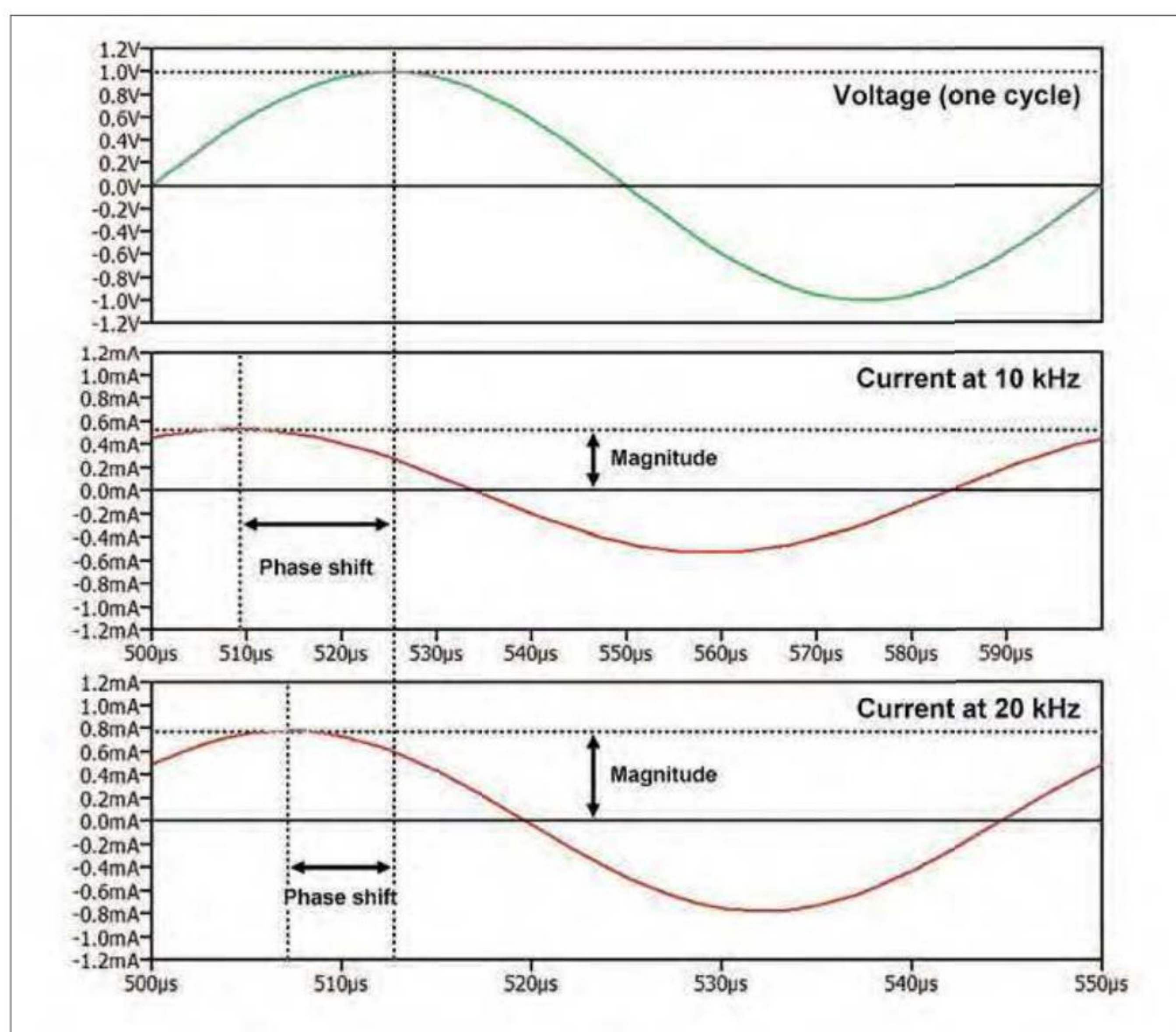


Fig.2. One cycle of the current waveform through an impedance for the same applied voltage amplitude at two frequencies. The current shift in time with respect to the applied voltage and the amplitude of the current both vary with frequency.

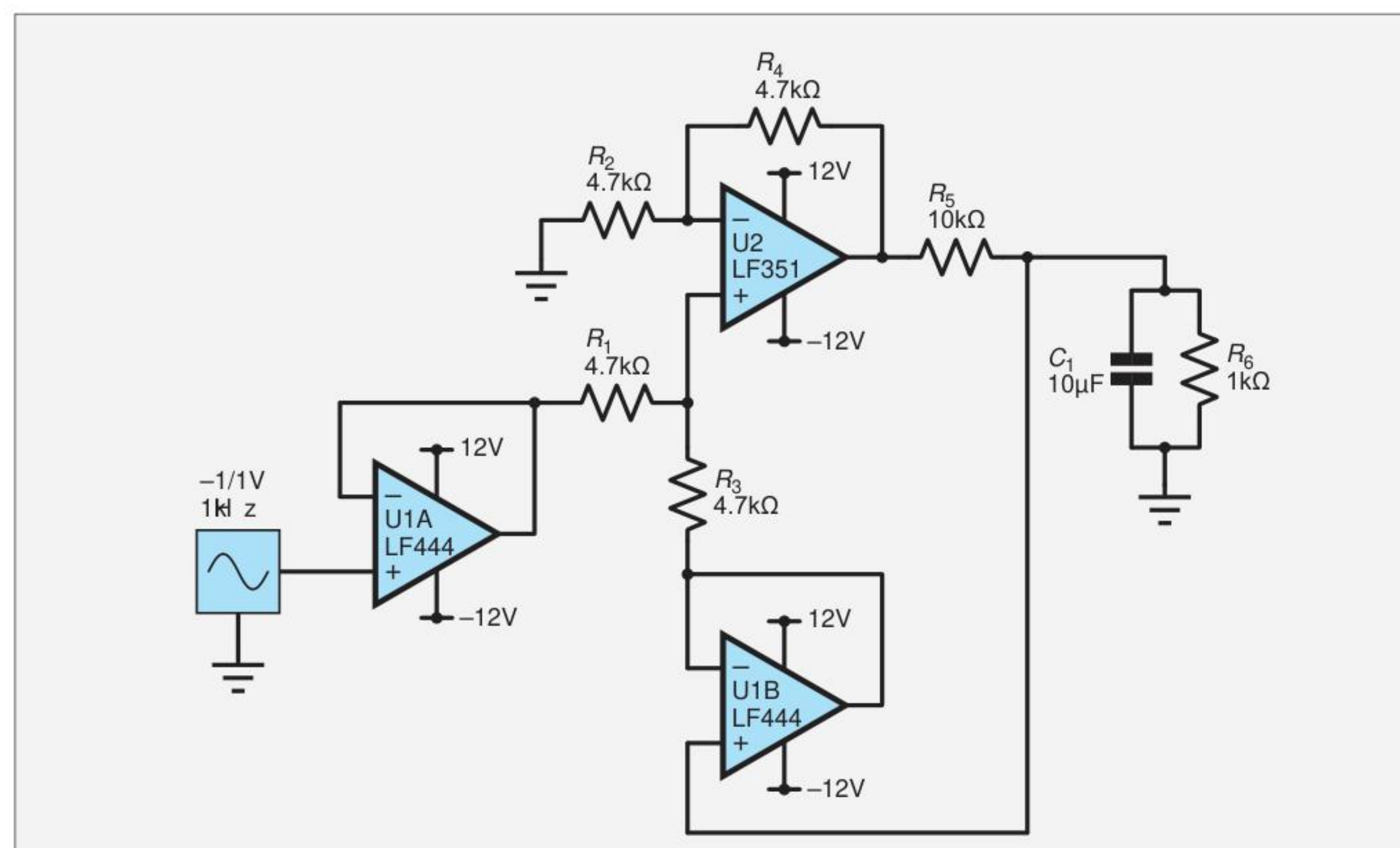


Fig.1. Fariz's impedance measurement circuit.

Impedance

Impedance (symbol Z) is the AC version of resistance – the relationship between the applied voltage and resulting current that flows. More specifically $Z = V/I$, which superficially looks the same as the similar resistance relationship, $R = V/I$. The difference is that when dealing with AC signals we are concerned with both the magnitude (sinewave peak amplitude) and phase (relative time) relationship of the voltage and current, and impedance has to take account of this.

If we apply a sinewave to a resistor the voltage and current follow one another exactly – the peak in current occurs at the same time as the peak in voltage. The same is not true for inductors and capacitors. If we apply a sinewave to a pure capacitor the peak in current will occur a quarter of

the sinewave cycle earlier than the voltage peak (we refer to this as current leading voltage, or voltage lagging current). The time shift between voltage and current is usually expressed as an angle, where one cycle of the waveform is 360° . Thus, the current in a pure *capacitor* *leads* the voltage by 90° . For a pure *inductor* the current *lags* the voltage by 90° .

For a pure resistor (R) the resistance does not change with the frequency of the applied voltage or current. For a pure inductor (L) the effective ‘resistance’ increases with frequency; that is, the magnitude of the current will decrease with frequency for the same magnitude of applied voltage. A pure inductor is a short circuit for DC and resists current flow more as frequency increases. For a pure capacitor (C) the effective resistance decreases with frequency – it is an open circuit for DC and resists current flow less as frequency increases.

For impedances other than pure R , L or C , the phase shift may be other than 0° or $\pm 90^\circ$ and may vary with frequency along with the effective resistance. Fig.2 shows an example of the waveforms for a particular impedance. A 1.0V AC waveform is applied to the impedance. The resulting current is shown for two different frequencies for one cycle of the waveform. The peak in voltage occurs after the peak in current (voltage lags), but the amount of voltage lag varies with frequency. In Fig.2 this is about 60° at 10kHz and 40° at 20kHz. The amplitude of the current also varies with frequency.

A single number (for ‘the voltage’, ‘the current’, or ‘the resistance’) cannot encompass both the amplitude and phase shift. We use two values – the magnitude and the phase shift angle to describe a waveform or an impedance – as shown in Fig.2. For example at 20kHz the current magnitude is about 0.78mA, so with an applied voltage of magnitude 1.0 V this indicates a ‘resistance’ of $1.0/0.78\text{mA} = 1.3\text{k}\Omega$, but this alone does not inform us of the phase shift and therefore the impedance. However we can write $Z = 1300\angle -40^\circ$ to cover the magnitude and the 40° voltage lag ($\angle$ is an ‘angle’ symbol).

Complex numbers

It turns out that the ‘magnitude-plus-phase’ annotation is not the most powerful way of representing impedance for mathematical circuit analysis; instead, complex numbers are often used. Complex numbers are two dimensional and therefore able to represent both amplitude and phase. The two parts of a complex number are called the ‘real’ and ‘imaginary’ parts. The term ‘imaginary’ is employed because the square root of -1 is involved. There is no ‘normal’ number which when multiplied by itself gives -1 , but it is a

very useful mathematical concept for representing real things, such as the behaviour of electronic circuits.

In pure mathematics the square root of -1 is given the symbol i , but in electronics the symbol j is usually used to avoid confusion with the symbol for current. A complex number is of the form: $a + jb$ in which a and b are normal numbers and $j^2 = -1$. a is the real part of the complex number and b is the imaginary part. Impedance is represented by the complex number $Z = R + jX$ in which R is resistance and X is reactance. A resistor has impedance $Z = R$, that is, the impedance is a purely real number equal to the resistance. An inductor has impedance $Z = j2\pi fL$, that is, it is purely imaginary value that increases in proportion to frequency (f). A capacitor has impedance $Z = 1/j2\pi fC$, that is, it is a purely imaginary value that decreases in inverse proportion to frequency.

Complex numbers and the magnitude-plus-phase version of signals and impedances represent the same information, and we can convert between the two. For a complex value $a + jb$ the magnitude is $\sqrt{a^2 + b^2}$ and the phase (angle) is $\tan^{-1}(b/a)$. $\tan^{-1}$ is the inverse tangent or arctangent function, which is commonly available on scientific calculators or ‘google calculator’. For a magnitude and phase impedance of $|Z|\angle\phi$ (magnitude $|Z|$ and angle ϕ – Greek letter phi) the real part (a) is $|Z|\cos(\phi)$ and the imaginary (b) part is $|Z|\sin(\phi)$.

Impedance analysis and spectroscopy

It is useful to be able to measure the electrical impedance of things, and because impedance varies with frequency we often need to measure impedance over a wide range of frequencies. Impedance measurement instruments – which is what Fariz is trying to build – typically produce plots of the real and imaginary parts of impedance (and/or magnitude and angle) over a wide range of frequencies. They apply a voltage or current and measure the resulting current or voltage signal to determine the amplitude and phase relationship. Often, the applied signal is also measured rather than just assuming its value from the signal generation process settings – this is the issue that Fariz is asking about.

In electronics we might be interested in characterising electronic components. All real resistors, capacitors and inductors have some level of the other two properties. For example, an inductor will have some resistance and some capacitance, but things are often more complex than just

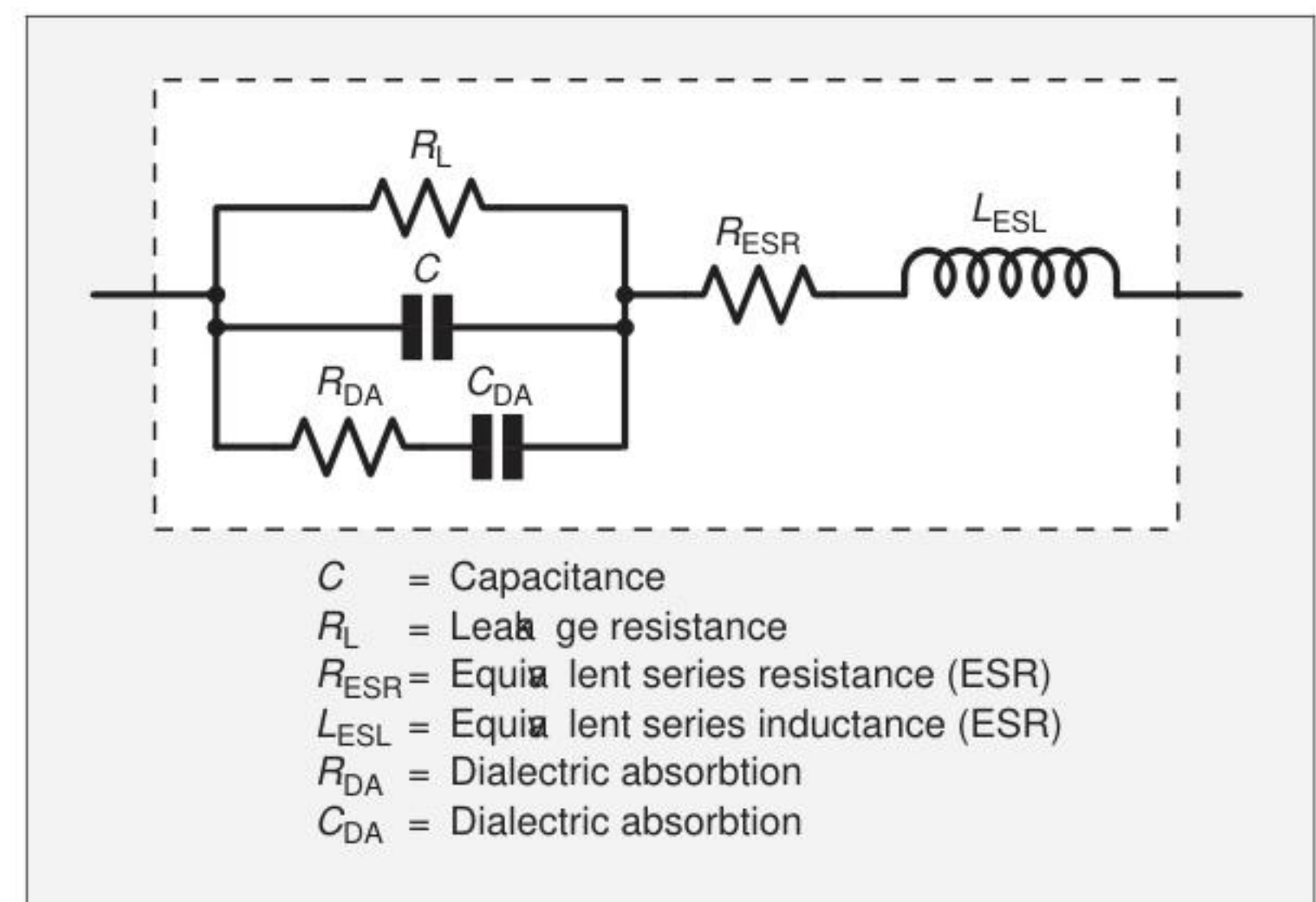


Fig.3. Model of a real capacitance – the various non-ideal elements of the capacitor (everything except C) mean that the impedance variation with frequency will be different from and more complex than for an ideal capacitor.

some additional R , L or C in series or parallel with the component. Fig.3 shows a commonly used model – an equivalent circuit – for a real capacitor. Even more complex models are also used. Careful impedance measurement over a wide frequency range can determine the values of the non-ideal characteristics of devices, which are often very important in high performance applications.

Impedance measurement over a range of frequencies (hence ‘spectroscopy’) is not just used for characterising electronic components, but has a wide range of uses in science and industry. Examples in biology and medicine include measurement of tissue and cell properties and the status of fluids in patient’s bodies. It is also used in biosensors (to detect certain pathogens). It can be used to characterise various materials, including ceramics, polymers, coatings and foodstuffs. It can be used to measure corrosion. It is used in chemistry for the measurement of electrochemical processes.

Accurate impedance measurement, particularly at high frequencies is not easy due to the fact that any wiring between the instrument and the test item will have impedance properties which might have to be compensated for and because the electronics driving and measuring the signals will be subject to imperfections that may introduce errors.

Howland current source

The circuit posted by Fariz is known as a ‘Howland current source’ (or ‘Howland current pump’). It is shown in its most basic form in Fig.4, but there are a number of variations. The circuit resembles a standard op amp differential amplifier, which it would be if R_4 were not present. R_4 is interesting in that it provides *positive* feedback. An advantage of the Howland current source, compared with some other common current-source circuits is that it can both sink and source current. That is, it can drive a bidirectional (positive

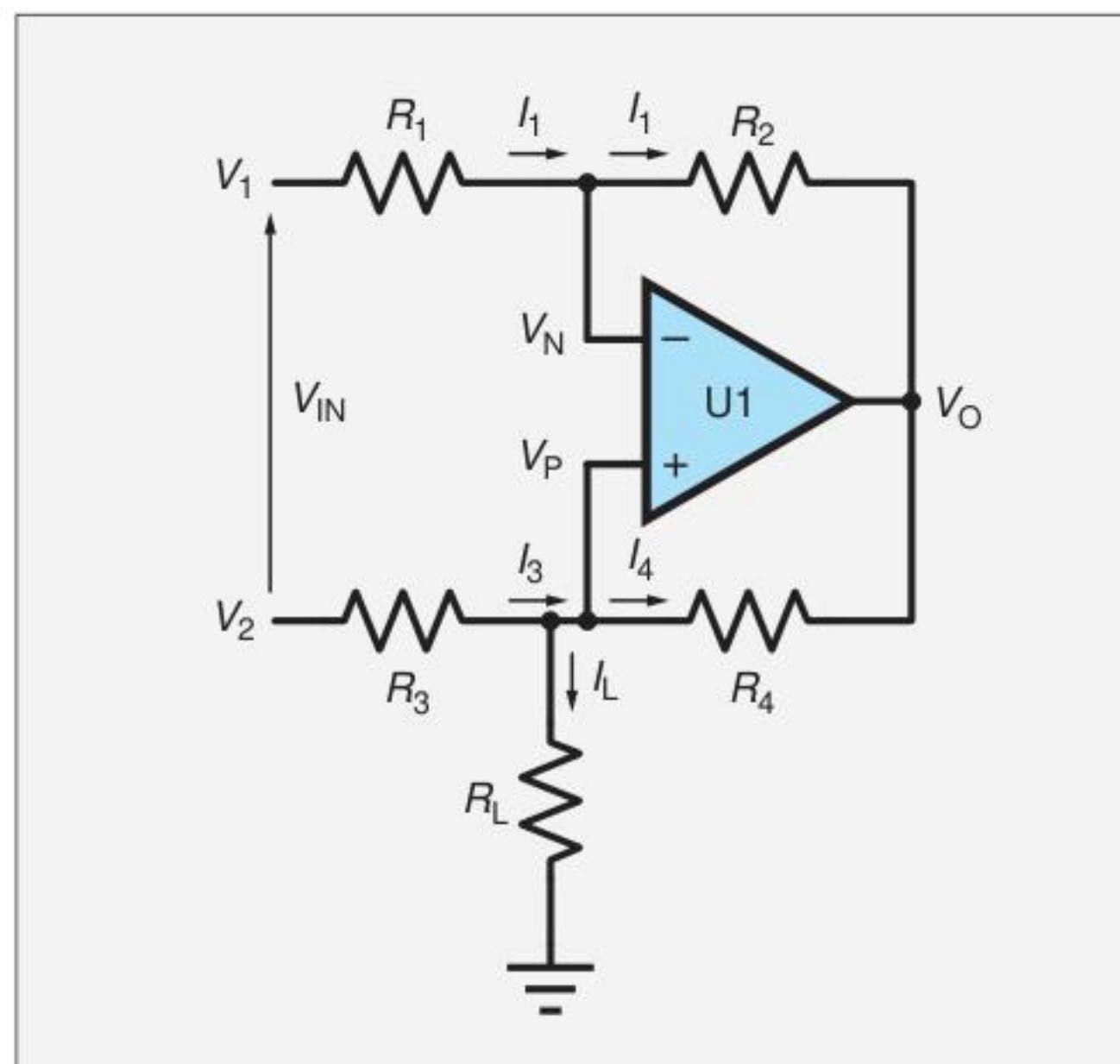


Fig.4. Basic Howland current source.

and negative) current signal through the load (R_L in Fig.4).

The Howland current source uses matched resistor ratios, specifically $R_2/R_1 = R_3/R_4$ in Fig.4. It is not uncommon for all four of these resistors to have the same value. The circuit can be analysed without making initial assumptions about these ratios, but the resulting equations are a bit cumbersome. We will shortly do a simplified analysis to keep the algebra to minimum.

Being a differential circuit, the input voltage V_{IN} is applied between the two inputs, rather than referenced to ground, but can we also consider the voltage on the two inputs separately as V_1 and V_2 . Often, one input is grounded and an input voltage is applied via the other input to control the output current (as in Fariz's circuit in Fig.1).

Circuit analysis

If we assume that the op amp in Fig.4 has very high gain (ideally infinite) and is not saturated (ie, operating normally, with outputs not forced to minimum or maximum), then we can assume that its input terminal voltages are effectively equal ($V_N = V_P = V_X$). Any significant difference between V_N and V_P would result in saturation due to the high gain.

We will also assume that no current flows into the op amp due to its infinite input impedance and zero bias currents (in the ideal case). Thus the current in R_1 will be the same as the current in R_2 . So we can write:

$$I_1 = (V_1 - V_X)/R_1 = (V_X - V_O)/R_2$$

This expression is simply Ohm's law, relating voltage across the resistors due to the current through them. Since the equal resistor ratios are equal by design, that is, $R_2/R_1 = R_3/R_4$, we can also write this equation as:

$$I_1 = (V_1 - V_X)/R_3 = (V_X - V_O)/R_4$$

The current in R_3 will be:

$$I_3 = (V_2 - V_X)/R_3$$

And the current in R_4 is:

$$I_4 = (V_X - V_O)/R_4$$

However, unlike the currents in R_1 and R_2 , I_3 and I_4 are not equal. I_3 splits and flows through R_L and R_4 . Again, assuming no current into the op amp, Kirchhoff's Current Law tells us that I_3 is equal to the sum of I_4 and I_L , that is:

$$I_3 = I_L + I_4$$

Substituting the voltage/resistance expressions (from above) for the currents into this expression we get:

$$(V_2 - V_X)/R_3 = I_L + (V_X - V_O)/R_4$$

Looking at the second version of our equation for I_1 , we see:

$$(V_X - V_O)/R_4 = (V_1 - V_X)/R_3$$

So we can write this as:

$$(V_2 - V_X)/R_3 = I_L + (V_1 - V_X)/R_3$$

V_X cancels in this equation, and then we can rearrange it to get:

$$I_L = (V_2 - V_1)/R_3$$

Thus the current in the load does not depend on the value of R_L and is set by the input voltage and R_3 .

Like all circuits, the Howland current source has its limits and imperfections. One problem is that the circuit depends on exact matching of the resistor ratios. Precision resistors (0.1% or better) should be used, otherwise the internal resistance of the current source may not be very high (it can even be negative).

Improvements

A disadvantage of the basic Howland current source is its restricted voltage range. V_O is larger than the voltage across the load, so if the load voltage needs to increase to maintain the current the op amp will saturate before the load voltage is anywhere near the supply. The circuit in Fig.5 is a modified version of the Howland current source which overcomes some of the issues with the basic design, including the voltage range.

In the circuit in Fig.5, R_4 from Fig.4 is split into R_4 and R_5 . R_5 is much smaller than R_4 so the voltage drop across R_5 in Fig.5 is much less than for R_4 in Fig.4. This means that the load voltage is much closer to the op amp output voltage and its output range is not 'wasted' on the R_4 drop.

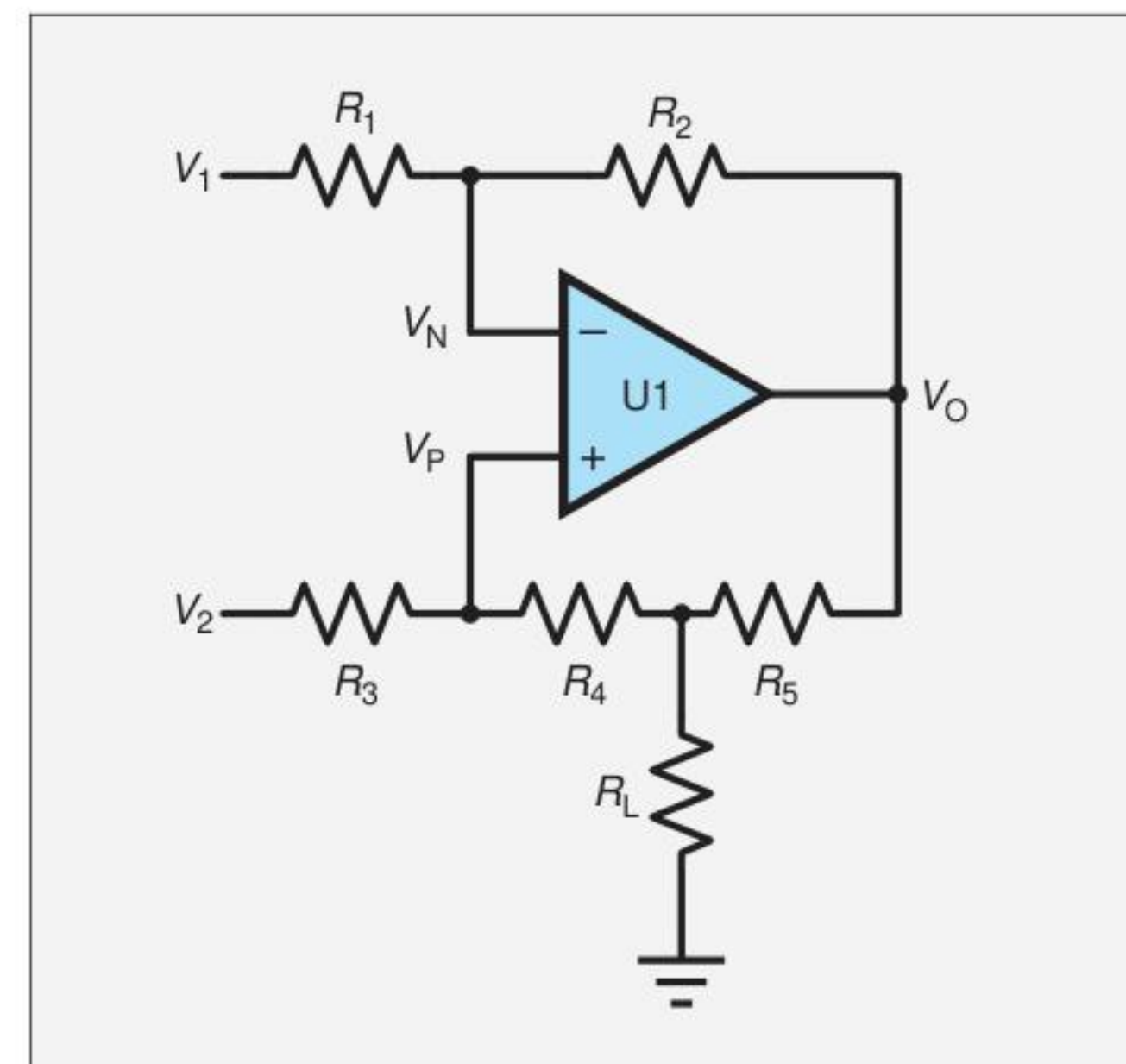


Fig.5. Improved Howland current source.

The circuit in Fig.5 requires the resistor ratios to be matched such that:

$$R_2/R_1 = R_3/(R_4 + R_5)$$

As with the basic circuit, high-precision resistors must be used to achieve accurate matching of these ratios if good performance (high internal resistance of the current source) is to be achieved. In both circuits it is possible to use various trimmer arrangements to allow the matching to be adjusted.

Even with good matching, the circuit in Fig.5 has limitations. More detailed analysis shows that if R_2 is larger the current is more constant (as ideally required as R_L varies). However, a large R_2 limits the speed and precision of the circuit. This can be overcome by adding a buffer amplifier: A1 in Fig.6. With this buffer in place, all the current through R_5 flows through R_L . With resistor ratios $R_2/R_1 = R_3/R_4 = k$ the output current is:

$$I_L = (V_2 - V_1)/kR_5$$

This is the form of Howland current source used by Fariz (Fig.1). Fuller details of this circuit and further enhancements can be found in an article for *Analog Dialogue* (from Analog Devices) by Nick Jiang, see: <http://bit.ly/pe-may20-ad>

Current measurement

There are two basic approaches to measuring the current applied to an impedance under test – these are shown in Fig.7 and Fig.8. In both cases we show a current source driving the impedance under test (Z) but it could be driven from a voltage source. Also, in both cases we show a differential amplifier being used to measure the voltage across Z – we need this signal along with the current in order to measure impedance.

The first current measurement approach is shown in Fig.7 – it uses a sense resistor and measures the voltage across it using a differential amplifier. The current supplied to Z also flows through the sense resistor

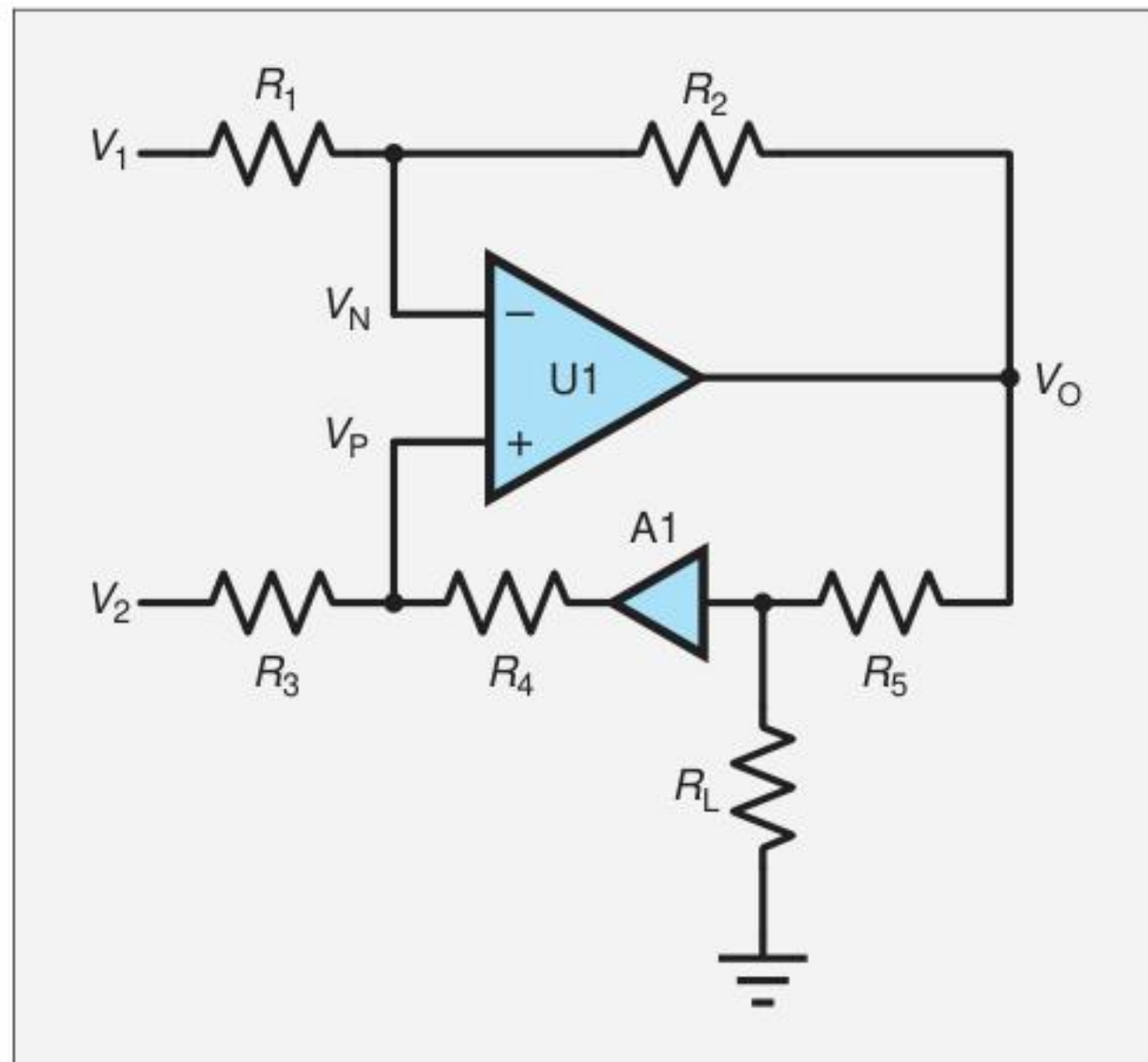


Fig.6. Howland current source with feedback buffer.

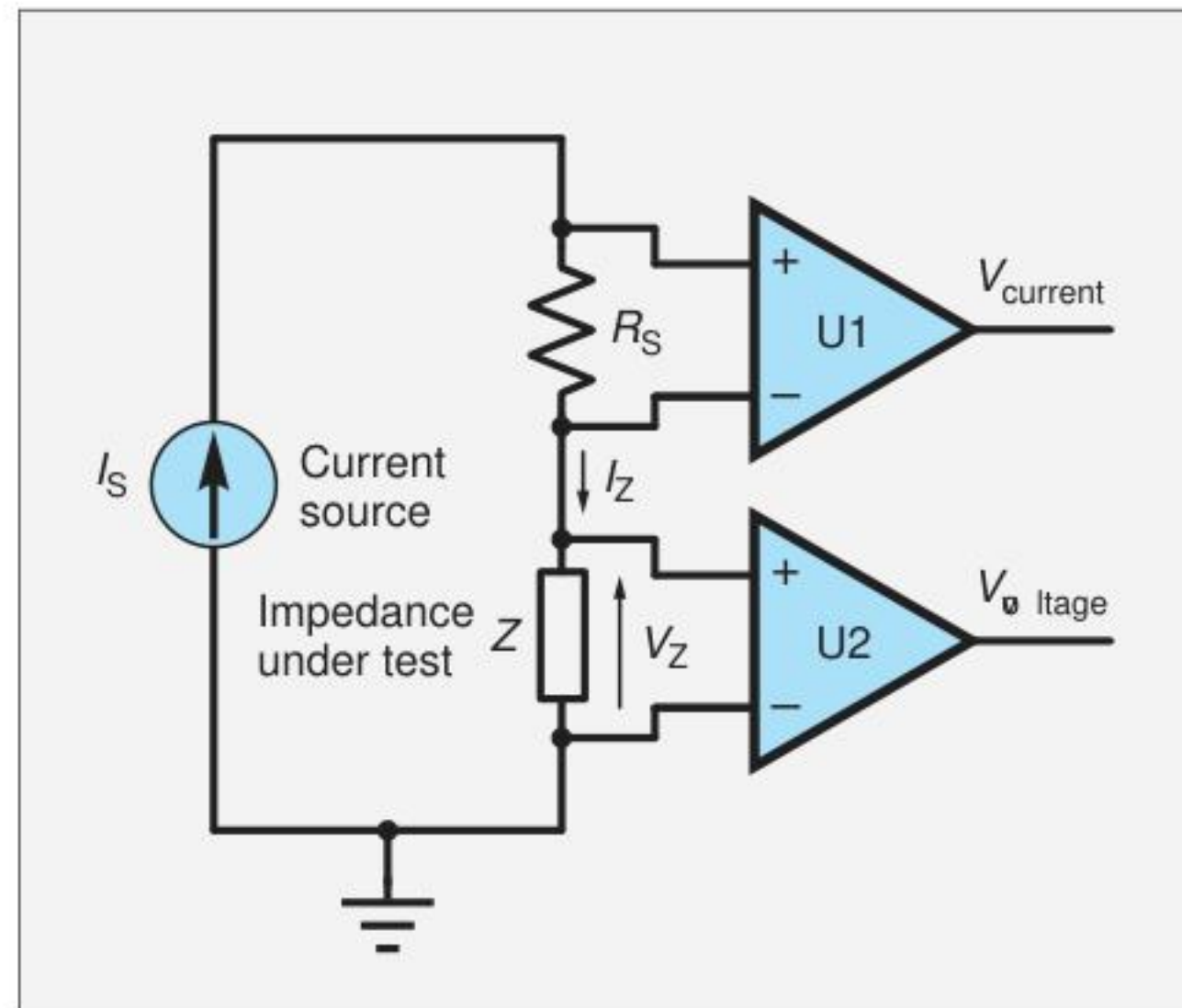


Fig.7. Current measurement circuit using a sense resistor. Voltage measurement also shown.

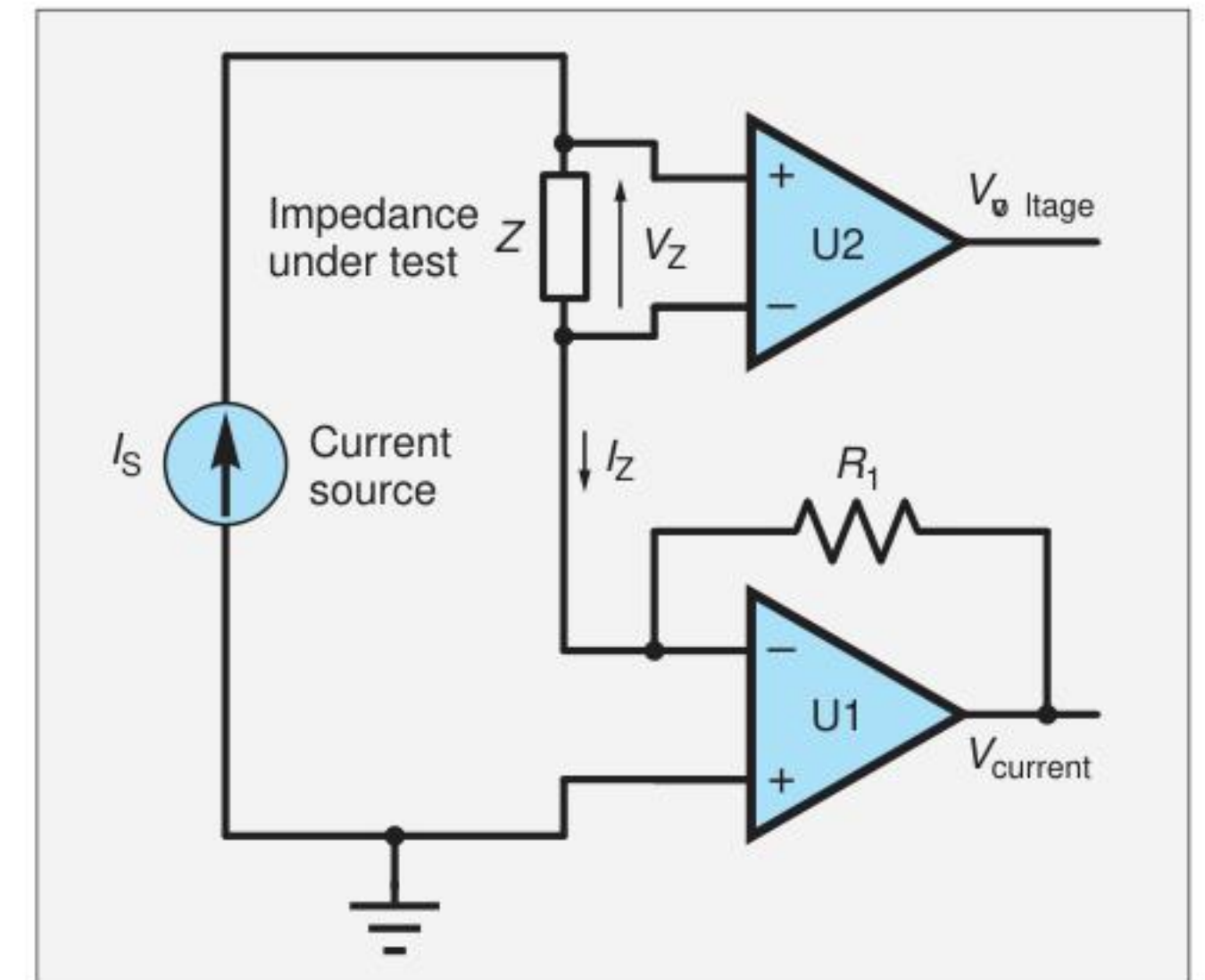


Fig.8. Measurement circuit using a transimpedance amplifier; voltage measurement also shown.

R_S and creates a voltage drop, $R_S I_Z$, which is amplified by U1 to produce an output voltage proportional to the current in Z: $V_{\text{current}} = A_1 R_S I_Z$, where A_1 is the voltage gain of U1. The voltage across Z is measured using U2; its output is $V_{\text{voltage}} = A_2 V_Z$, where A_2 is the voltage gain of U1.

The differential amplifiers used in the circuit in Fig.7 must have very high input impedance and very low bias currents. Any current flowing into the differential amplifiers will cause discrepancies between the measured current and that flowing into the impedance under test. These amplifiers must also have very good common-mode rejection ratios (CMRR) so that their outputs are only dependent on differential inputs; again, if this is not the case measurement errors will occur. The same applies to the differential amplifier in Fig.8.

Transimpedance amplifier

The second current measurement approach is shown in Fig.8 – it uses a transimpedance amplifier implemented using op amp U1 and resistor R_1 . The voltage across Z is measured using U2 in the same way as for the circuit in Fig.7.

A transimpedance amplifier has an input of current and an output of voltage, so the gain ($V_{\text{out}}/I_{\text{in}}$) has units of ohms (compare $V/I = R$ in Ohm's Law). This circuit could also be called a 'transresistance amplifier', but the term 'transimpedance' is more general and more commonly used. The term 'transimpedance' is short for 'transfer impedance' – with 'transfer' indicating an input-to-output relationship, rather than the direct voltage-across to current-through relationship of a basic impedance or resistor.

Looking at Fig.8, we see that the impedance under test is not connected to ground. However, using the same argument as for the two inputs of the op amp in the Howland current source being at the same voltage, we note that the inverting input of the op amp must be a voltage very close to 0V under normal operation. With an ideal op amp, the inverting input would be exactly at 0V. This behaviour of an op amp amplifier with the inverting input grounded is referred to as a 'virtual' earth (or 'virtual' ground).

Given the impedance is not directly connected to ground – where does the current actually go? There are two possibilities – through resistor R_1 , or into the op amp. The amount of current flowing into the op amp depends on its input impedance and its input bias current. For an ideal op amp, the input bias current is zero and the input impedance is infinite. Therefore, no current flows into the op amp in the ideal version of this circuit, which means all of the input current must flow through R_1 . This makes it easy to find the voltage dropped across R_1 – it is simply $I_Z R_1$ by Ohm's law. We also know from our previous discussion of virtual earth that the input end of the resistor is at 0V, so the other end must be at $-I_Z R_1$ volts. So $V_{\text{current}} = -R_1 I_Z$.

Real op amps are available with very high input impedances and very low input bias currents. Some op amps are specifically designed for use in transimpedance configurations.

Full-measurement system

The current source and voltage and current measurement circuits do not form a complete impedance analysis system. The drive signal needs to be generated over the required range of frequencies and the measured voltage and current signals must be processed to obtain the impedance values (typically the real and imaginary parts). This can be done digitally by sampling the V_{voltage} and V_{current} waveforms using high speed data converters and using digital signal processing (DSP) to obtain the impedance values.

ICs are available, which are targeted at bio-impedance/electrochemical impedance measurement markets, such as in healthcare, which implement the functionality of impedance measurement on a single chip. For example, Analog devices produce the AD5940 'High Precision, Impedance & Electrochemical Front End' and ADuCM350 'Configurable Impedance Network Analyzer & Potentiostat with Integrated Cortex M3 Core'.



CRICKLEWOOD ELECTRONICS

Established 1981

Your best bet since MAPLIN

Chock-a-Block with Stock

Visit: www.cricklewoodelectronics.com

Or phone our friendly knowledgeable staff on **020 8452 0161**

Components • Audio • Video • Connectors • Cables
Arduino • Test Equipment etc, etc



Visit our Shop, Call or Buy online at:
www.cricklewoodelectronics.com

020 8452 0161

Visit our shop at:
40-42 Cricklewood Broadway
London NW2 3ET

PICn'Mix

Mike Hibbett's column for PIC project enlightenment and related topics

Audio Spectrum Analyser – bandwidth expansion

It's a bumper issue this month as we complete our *Audio Spectrum Analyser* project.

The circuit is based around a dsPIC33 DSP (digital signal processing) microcontroller and a low-cost 320 × 240 colour LCD display sourced from eBay.

The software has been developed using Microchip's free FFT (fast Fourier transform) library, and Adafruit's free graphics library that was compatible with our display. Those libraries provided the complex software, leaving us with figuring out how to use and modify them to work with our processor of choice, and our schematic. Nowadays, for the many projects that make use of freely available pre-existing source code, that modification work is the hard part. Once done, adding new features like changing the operation of the system in response to a keypress or drawing cool logos is a relatively simple task, fun to do and highly rewarding.

We complete the project this month by adding functionality to the buttons, testing out the new LDO voltage regulator, and building a 3D-printed enclosure.

Display recycling

The first step was to salvage the LCD display from the PCB assembly of the previous design; we had only purchased one LCD module and it would take weeks for a new one to arrive from eBay. Separating the boards was done by cutting each pin from the two headers binding the PCBs together. The next step was to remove the pins one by one from the LCD module with the aid of a soldering iron

and then cleaning up the holes for fitting new a new header strip. When cutting off header pins, leave enough length on the pins in the LCD module so that you can easily pull on them with pliers. Once done and with the plastic spacer carefully cut away, each hole was cleaned up with solder wick to allow a new 0.1-inch strip of header pins to be inserted. The original PCB was discarded. We could have salvaged the processor, but at a cost of just a few pounds, we did not want to take the risk of building a circuit using an IC with heat or mechanical damage. True enough, with care, removal is possible, and you may find it an interesting desoldering challenge! We, however, were on a tight timescale, so the board was discarded. (We did salvage the electret microphone, a simple two-lead device – plus, it was the only one we had. Removal is a simple job of heating both leads simultaneously. This could be done quickly with a low risk of damaging the part.)

New PCB

Now we can start to populate the new PCB. First though, let's look at the PCB under the microscope to see the manufacturing quality. As you can see in Fig.1, the alignment of the key manufacturing processes is excellent. The drill holes are very well centred in the pads, and the solder resist layer – which is very important to help prevent solder bridges between component pads – is both well aligned around the pads, and also hugs very close to each pad – maximising the amount of this protective layer that is available. This is a very good job by PCBWay.

Choose your PSU

A key point to note in the schematic, shown in Fig.2, is that we now allow for two power supply choices – if you build this circuit, populate only one! The choice is based around IC1, a switching regulator that has a wide input voltage range, and IC3, a simple linear regulator. We discussed the pros and cons of each in the previous article; this month, we are populating the linear regulator version,

as it offers the lowest noise into the rest of the circuit (the original PCB used the switching regulator, and we were disappointed by the additional noise, although it did not appear to limit performance.)

The linear regulator circuit takes an input of 3.3V to 6V – ideal for four AA batteries – so we will power the circuit from this supply. We will also validate on a bench power supply what the current consumption is across that voltage range, so we can get an expectation of the battery life. The inclusion of an on-off switch in the enclosure design will ensure that we prolong battery life as long as possible.

Returning to FFTs

We start our design upgrade by considering the more complex requirement, which affects both hardware and software change – moving from a maximum input signal of 1kHz to a maximum of 20kHz, covering the full human hearing range.

Let's recap on our hardware design, as that limits some of our design choices. First, our spectrum analyser display is fixed at 256 data points, as we only have 256 horizontal pixels to play with. There is no point adding more data points; we cannot display them. Using extra data points would mean having to average those extra data points into one – which is no better than simply using a lower FFT size. So, a 256-point FFT remains our design specification.

What we are changing, however, is the sample frequency, the rate at which we perform an analogue-to-digital conversion on the input signal. Previously, we used a sample rate of 2kHz, giving us the ability to display signals up to 1kHz. We would like to improve the design to be able to display signals up to 20kHz (now way beyond your author's hearing range,) which will require us to increase the rate at which we perform analogue-to-digital conversions from 2kHz to 40kHz. That is well within the capabilities of the dsPIC33's ADC peripheral and should pose no problem to our application, as it does nothing else while collecting ADC samples.



Fig.1. New PCB, close up. The solder mask and drill alignment to the copper are excellent.

PIC n' Mix files

The programming files discussed in this article are available for download from the *PE* website.

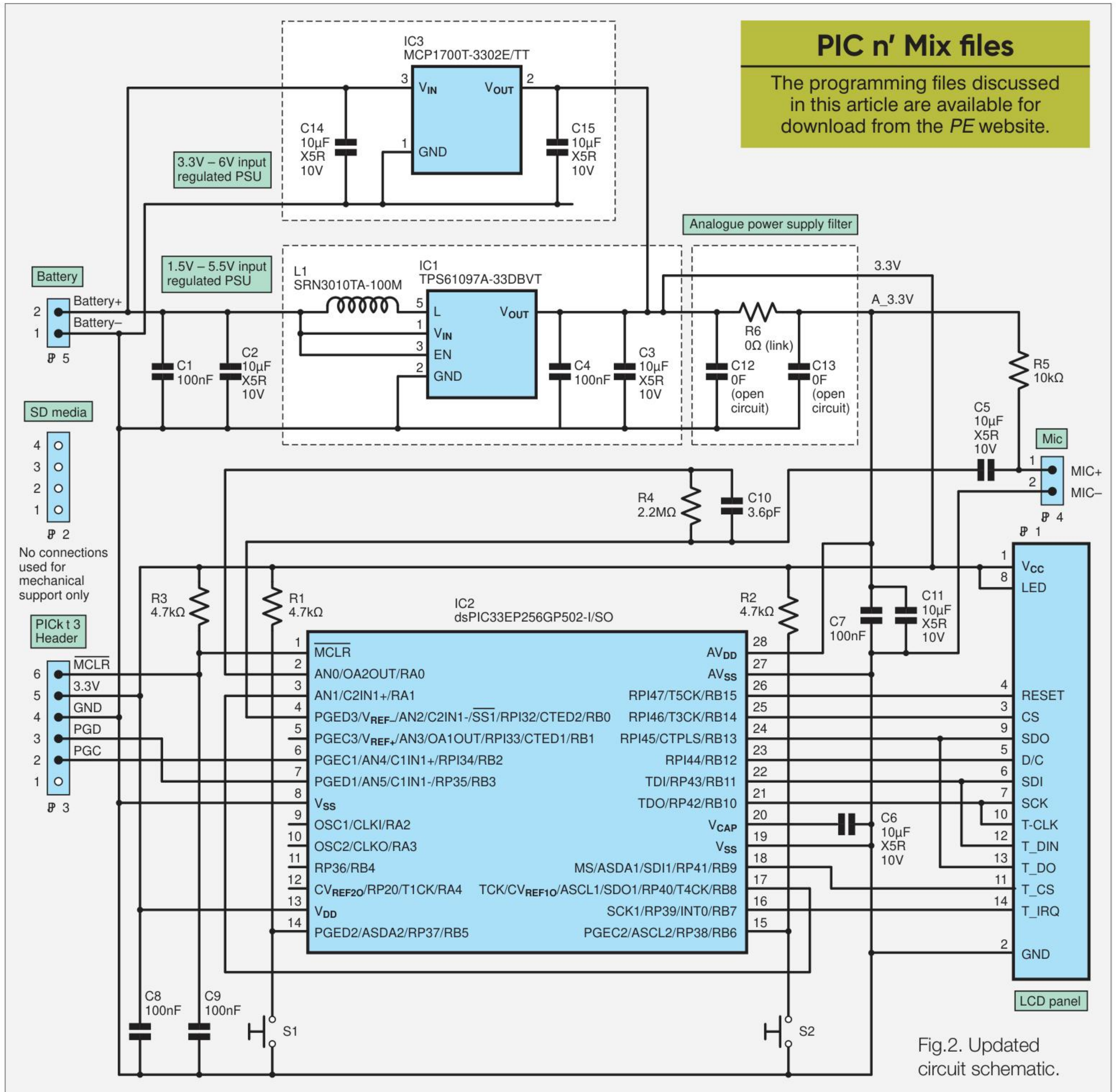


Fig.2. Updated circuit schematic.

This is a very simple change in the software. Just two lines of code change, as shown below:

```
#define SAMPLE_RATE 2000
Changes to:
#define SAMPLE_RATE 40000
```

And for the ADC peripheral:

```
PR1 = 32200;
Changes to:
PR1 = 1610;
```

Signal input

Now let's look at the hardware changes required to support this higher input frequency. The input circuit from the microphone to the ADC of the processor includes an amplifier, which is buried within the microcontroller itself, and so

the detail is not obvious from the schematic in Fig.2. The key point is that the amplifier includes two external components, a resistor and a capacitor (R4 and C10 on the schematic) which will provide some low-pass filtering as well as setting the gain of the amplifier. Filtering out higher frequency signals is desirable as these can appear as phantom signals at lower frequencies, through a process called aliasing. It's complicated, but the key point is to filter out unwanted higher frequency signals, otherwise they will interfere.

We will build the circuit up slowly so we can first test the microphone sensitivity, and to get a good understanding of the amount of gain we will need to set in the amplifier. We are going to do this empirically (ie, by guessing component values and measuring the results) rather

than through simulation, as we have no information on the microphone to model its characteristics.

We start by assembling the voltage regulator circuit based around IC3, R6 (using a zero-ohm link or very low value resistor), C14 and C15. Then we add the microphone circuit consisting of R5, set to a value of 10kΩ. C5 was not connected, as we want to test the microphone circuit and op amp circuits independently.

To help with these measurements we purchased an AFG (arbitrary function generator), the ISO-TECH AFG-21012 on eBay. At £150 it's a serious investment, but very useful for projects like these where you would like to see the true performance of a circuit when presented with AC signals. An arbitrary function generator has many other uses too, so it's a welcome addition to the lab. You can see our setup in Fig.3.



Fig.3. AFG – our brand new Arbitrary Function Generator.

We connected the AFG to a small loudspeaker and generated a 1kHz tone, placing the loudspeaker next to the microphone. Powering up the circuit – remember, the microphone requires power – we discovered that the microphone has an output that varies in amplitude from 5mV to 150mV_{pk-pk} (peak to peak) when the sound varies from quiet to loud.

We now know the amplification that we want to achieve; from 5mV – 150mV_{pk-pk} up to 3V_{pk-pk}, a gain of between 20 and 600. It's time to wire up the op amp and experiment with setting the gain. To do that, we must wire up the processor sub-system and load the original application, as the op amp must be configured by software. So, we assemble the remaining circuit.

The microphone amplifier circuit based around R4, C10, and the op amp built into the microcontroller can be viewed as the circuit shown in Fig.4. This is (loosely) an inverting amplifier, gain controlled by R4, with a low-pass filter determined by R4 and C10. The gain is the ratio of $R4/R_{in}$; we didn't include a resistor in the input circuit, relying on the impedance of the microphone. This drove a bit of trial and error to find values for R4, and we settled on 2.2MΩ, a gain of approximately 220. That's quite a large value resistor, but it made the device nicely sensitive to ambient level sounds. You can go higher, but the device quickly becomes too sensitive and can be easily overloaded, clipping the audio signal and generating misleading harmonics on the display. 2.2MΩ works really well. We implemented some

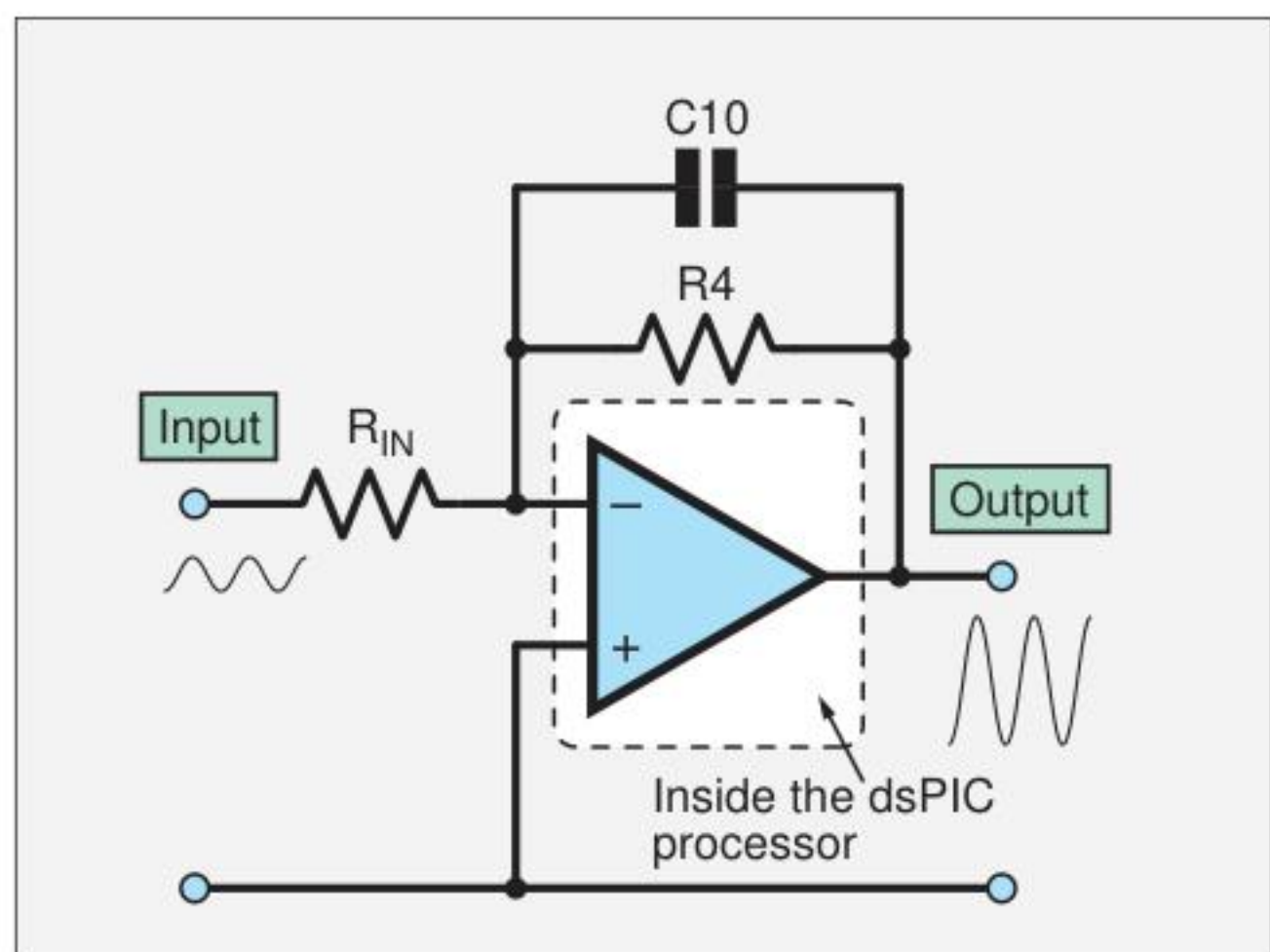


Fig.4. Microphone pre-amplifier circuit.

low-pass filtering by adding C10 with a value of 3.6pF, giving a cut-off frequency at approximately 20kHz. This will not be a very effective low-pass filter, but it will remove some of the higher frequency signals (such as oscillator and SPI bus noise from the board itself) being aliased into the displayed frequency range. Improving this circuit with a switchable op amp filter would have improved the quality of the displayed signal, but that can be considered a future improvement.

Why is attenuation for higher frequencies important? Having higher frequency signals present at the input to the ADC will result in aliasing – those higher frequency signals appearing to be lower in frequency and will end up being displayed on the LCD. You can see this effect in Fig.5. Filtering these out or minimising them greatly before they reach the ADC will stop them generating 'fake' signals on your display.

It was interesting playing with the sound generated by the AFG, especially as the frequency is raised out of hearing range, but with the spectrum analyser still faithfully displaying the signal. For the author, a quiet sound level stopped being audible at around 8kHz, but the signal was of course still visible on the display. Raising the frequency above 12kHz resulted in the displayed signal dropping to zero, probably as a result of the loudspeaker and microphone limitations, as these are not high-fidelity devices. Increasing the signal level output from the AFG saw the signal reappear, right up to 20kHz.

We've released a YouTube video demonstrating this effect, which can be viewed here: <https://youtu.be/mGIGxUU9w1k>

Software

First, we replaced the old *EPE* logo with the new *PE* one. We wrote a simple Python script to convert the magazine's logo to a data file suitable for including in the program. The source code for this is provided in the project download file, should you be interested in changing any of the graphics.

Next, we moved onto the more challenging software task – adding a user interface to the device, enabling the buttons to change the behaviour of the device.

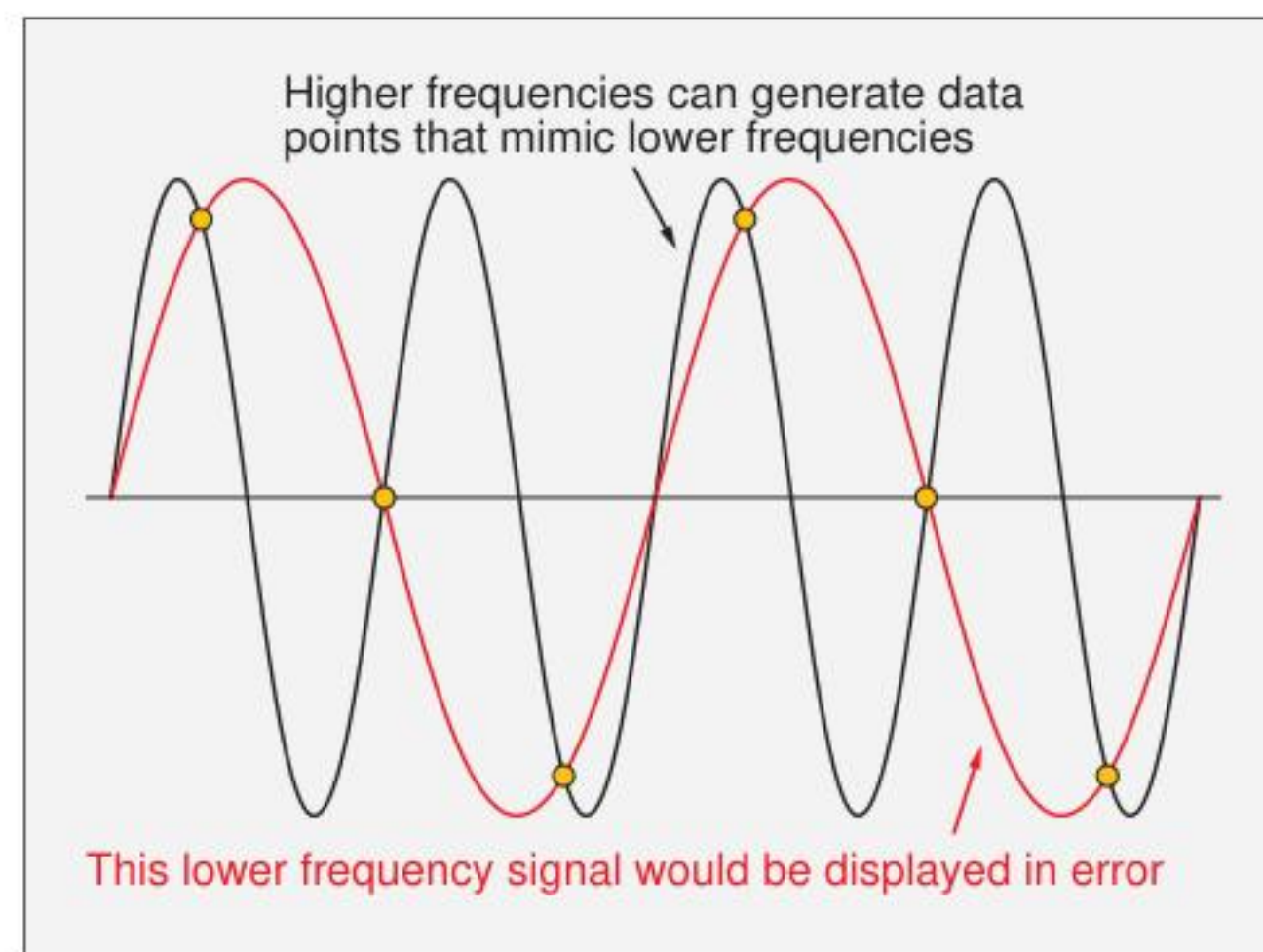


Fig.5. Aliasing – we need to filter out high frequencies that can give erroneous data.

In the previous article we gave the following desired functionality for the buttons:

Button A – On each press of the button, cycle between peak frequency display, peak trace hold, none. When active, the peak frequency will be displayed in the format nn.n Hz directly above the peak signal.

Button B – On pressing once, the display will show the frequency span for three seconds. On pressing the button again while the span is being displayed, the device will cycle through different span settings.

Those are good and clear requirements, but now we come to implement these requirements, looking at the display layout (as shown in Fig.6) we realised that there is a lot of available screen space unused in the lower left of the display. The width of this spare screen space is 60 pixels, enough to display ten characters in a 5×7 font. There is space for eighteen rows of characters, so there is plenty of room to display useful information continuously, irrespective of button presses. Doing so will also simplify our software design, so we chose to take this route.

The original Adafruit LCD driver software provided a simple 5×7 pixel character font, so we made use of that. We imported two functions from the original display driver, 'draw pixel' and 'draw character'. It took an hour to adjust the Adafruit code to suit the Microchip development environment, at which point we were successful at displaying text – but on its side. The Adafruit driver software expects the display to be driven in portrait mode, not landscape as we are using. No problem, back to hacking code. This driver is going to become somewhat specialised to our application.

The next step was to construct a 'draw string' function, to display the 'Peak' and 'Span' text, and the values calculated on each display update. The draw string routine was easy to implement, and then converting the calculated values into displayable strings was done using a standard 'C' function, `sprintf()`. No work required there.

Placing this text on the display revealed an issue – for the author at least – the text

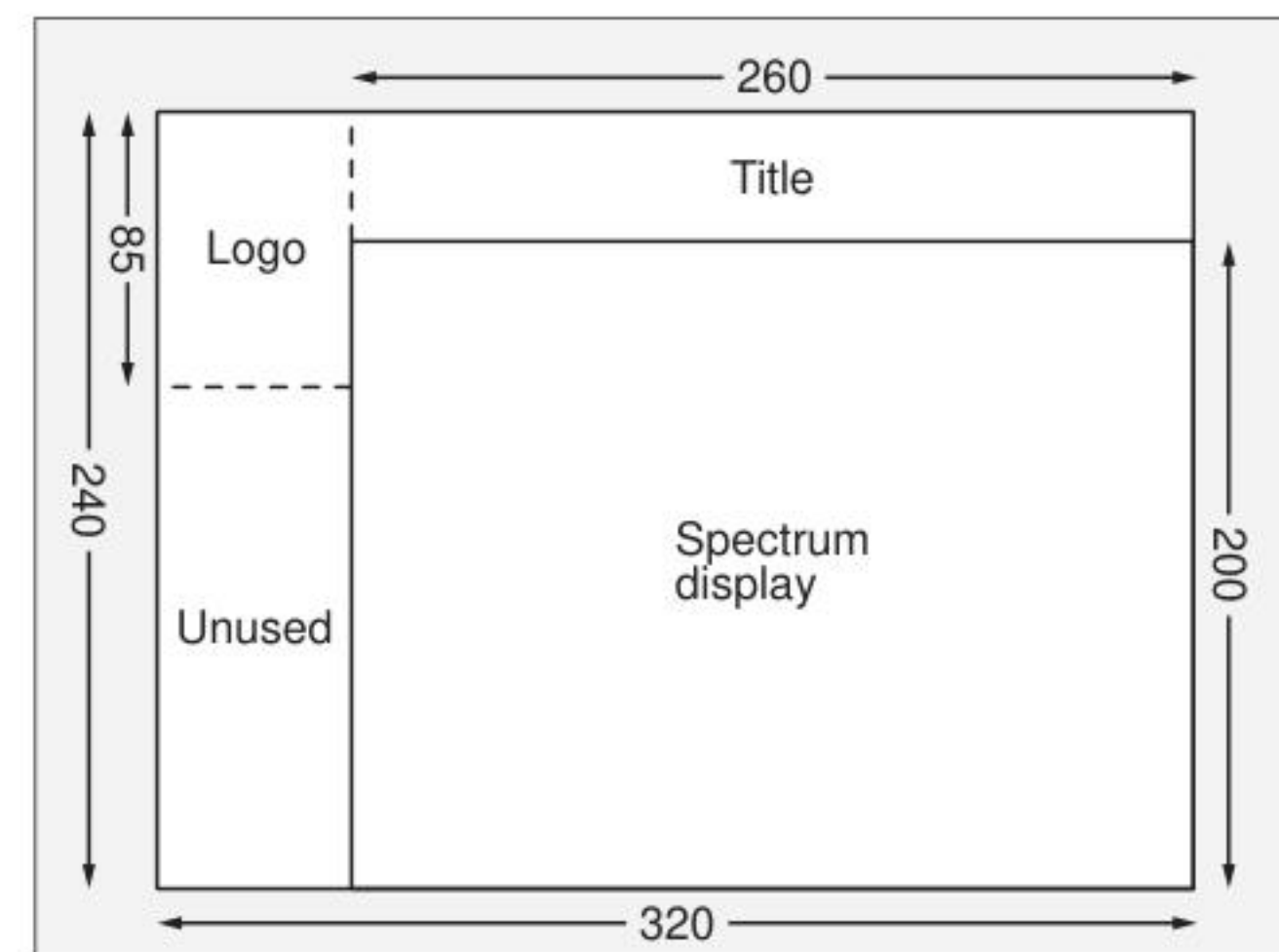


Fig.6. Mapping out our LCD real estate.

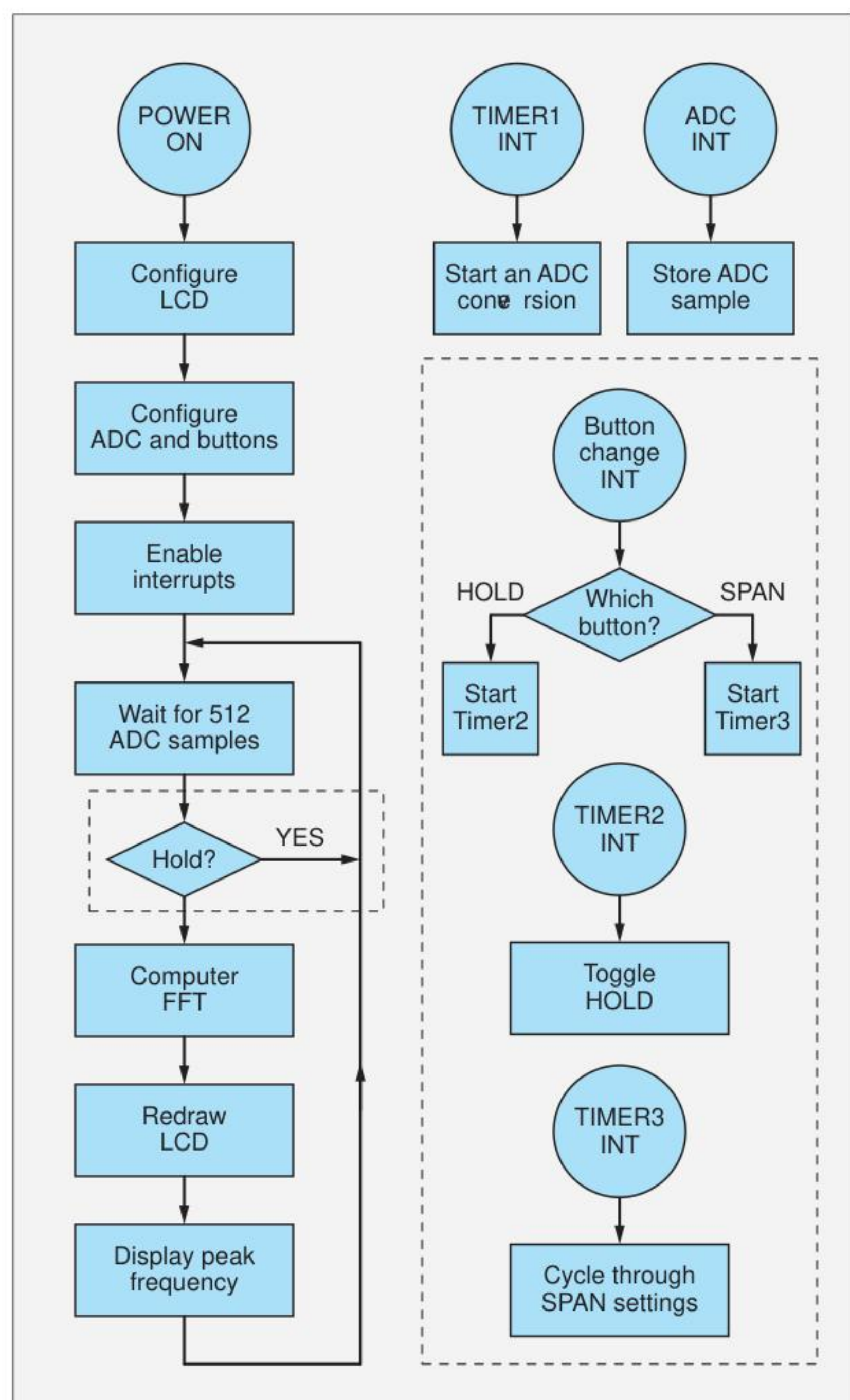


Fig.7. The final application flowchart. The parts in the dash line boxes are the additions for handling the button presses.

was too small to read without glasses. Fortunately, the Adafruit graphics library for printing characters has a ‘double size’ option, scaling the font to 10×14 pixels. This limited us to five characters across the display, but the text is very clear. We can accommodate a width of five characters in the design by cunning selection of display formatting.

Next, how to handle the buttons. As the program is a simple continuous loop, shown in Fig.7, we could have detected the button press within the loop. Two issues cause us to avoid this: at the lower ‘span’ frequency settings, the processor will spend a long time taking ADC samples so we cannot rely on the amount of time the loop takes; button press responses will be delayed. We also need to de-bounce the button press actions, which will require checking the button level 30 to 50ms after it has been pressed – this will slow down the display update. So, we take the more complicated route, and use an interrupt routine to detect when the buttons have been pressed or released, and a timer to trigger an action 30 to 50ms later to see if the button is still in the same state. This way we can react very quickly to key presses and be more efficient with the use of the processor, allowing it to concentrate on reading ADC values, computing the FFT, and displaying it.

those 30-50ms. When the timer expires, it will jump to an interrupt routine that will perform the desired action, if it finds that the button is still pressed. To simplify the software, we will use two timers, one for each button. The processor has five timers internally, so it’s not a waste of limited resources. You can see in the application flowchart in Fig.7 that the flow of execution is very simple. The code for this is actually quite simple; the complex part was finding out how to configure the timer, and what names are used by the compiler for the interrupt routines. Thankfully, these details are very, very similar between the different families of microcontrollers, so this task took just a couple of hours.

We took the opportunity to add several different sample rates, with the SPAN button cycling between them. Providing a range of sample rates yields a significant benefit to the design. The FFT algorithm is fixed at 512 ‘bins’, providing 256 data points. At a 40kHz sample rate, which equates to a maximum displayed frequency of 20kHz, the resolution of the display is 78Hz. This means that two signals close in frequency to each other, say a 50Hz and a 60Hz signal, would be lumped into the same vertical line. Providing a range of spans down to 500Hz means we can come down to a resolution

of 2Hz – which means those two signals will be clearly visible across the display. The only impact of doing this (there is always a cost!) is what is referred to as temporal resolution – at 500Hz the signal acquisition takes a long time, 256ms. It would be easy to reduce the peak frequency even lower to get a more accurate reading on lower frequency signals, but at each halving of the peak frequency, the sample time doubles. For some applications this is perfectly acceptable, and it is a simple change in the software if you would like to test it.

We also decided to display the word ‘HOLD’ when the HOLD button has been pressed, just for fun. It only added three lines of code.

With these changes completed, the software took just 23% of available code space on the processor, leaving over 64KB for future additions. You can see the finished project in Fig.8.

After testing it for a few minutes and then correcting two small software bugs, we removed the batteries and connected a bench power supply. We observed a continuous current draw of 120mA at 4V, and that the circuit continued to function down to 2.9V (at room temperature, at least.) Based on this, we decided to use just three AA batteries to power the project, which should provide 25 hours continuous use.

Handling button presses is often a tricky part of a project’s software design; there is no universal ‘one solution fits all’, and custom designs invariably involve interrupts and timers, which can be difficult to set up and debug.

Let’s start our design by remembering what our requirements are, and understanding what capabilities we have available on the processor. When a button’s state changes from ‘not pressed’ to ‘pressed’, de-bounce the press, then perform the action.

Here we are looking for interrupt capability on the pins that we are using as button input, PORTB pin 5, and PORT B pin 6. Fortunately, the processor provides a ‘change notification’ interrupt for all GPIO pins, so we have the ability to detect button press and button release.

Once a button press is detected we need to wait for a short time, typically 30-50ms, and re-check the input to see if the button is still pressed. If it is, perform whatever action is required. We will use a timer to provide the delay, to avoid tying the processor up during

3D printed enclosure

We’ve been using a 3D printer in the *PIC n’ Mix* lab for ten years now, since we first introduced the technology in February 2010. Then, 3D printers were an expensive novelty. Now, they have reduced in price from £1200 machines to £160 (the cost of the author’s current machine, a Creality Ender 3 – a printer we cannot praise enough.) By now, as hobbyists, we either own a 3D printer or know people who do and who are willing to print objects for us. From now on, expect to see 3D-printable enclosure designs for our projects, where appropriate.

We will leave the detail of designing a 3D-printed enclosure to another series of



Fig.8. The finished project, in its 3D-printed presentation case.

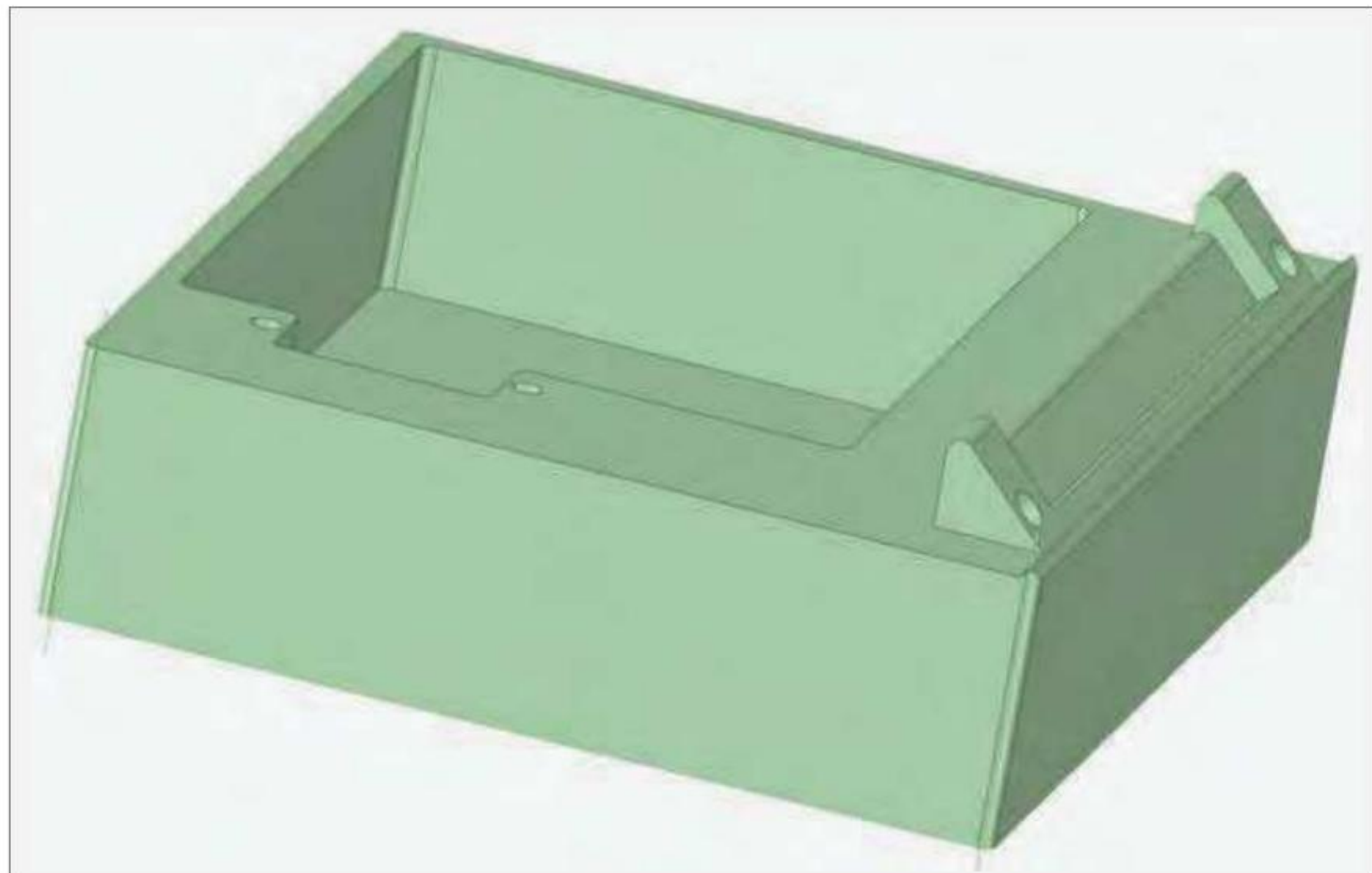


Fig.9. Enclosure design (fft-case.stl file available for download from the May 2020 page of the *PE* website).

articles, but the key point is that today, our recommendation is to use RS Components Design Spark Mechanical software for creating a design. The main reason is that this is an excellent application, easy to use and with many tutorials available online. There are better design applications available, both free and paid for (FreeCAD and Fusion 360 respectively) but for starting out in 3D CAD design with no previous experience, Design Spark Mechanical has, in our opinion, the best support for beginners. We've been using it for a year and are still happy with the capabilities.

There are two common techniques employed when designing enclosures for electronic products; design a two-part enclosure that provides mounting points on one part for the electronics, or design a 'chassis' for the electronics, and have that chassis

provide mounting points to the enclosure. We've seen both employed on complex products, but for this device the design is simple enough – four mounting posts, two buttons and a hole for the LCD – that we have decided to try the former approach. This reduces the number of 3D printed components required from three down to two, so it will be quicker and cheaper to build – on a hobbyist printer this will be very cheap, under a pound's worth of plastic filament.

For this project, we took a different approach, choosing to make a holder for the assembly, leaving the components exposed and clearly visible. We took this approach because we wanted to display the project at a Maker Faire, and it's more interesting to be able to see what's going on. You can see our design in Fig.9, created with the free design tool RS Design Spark Mechanical.

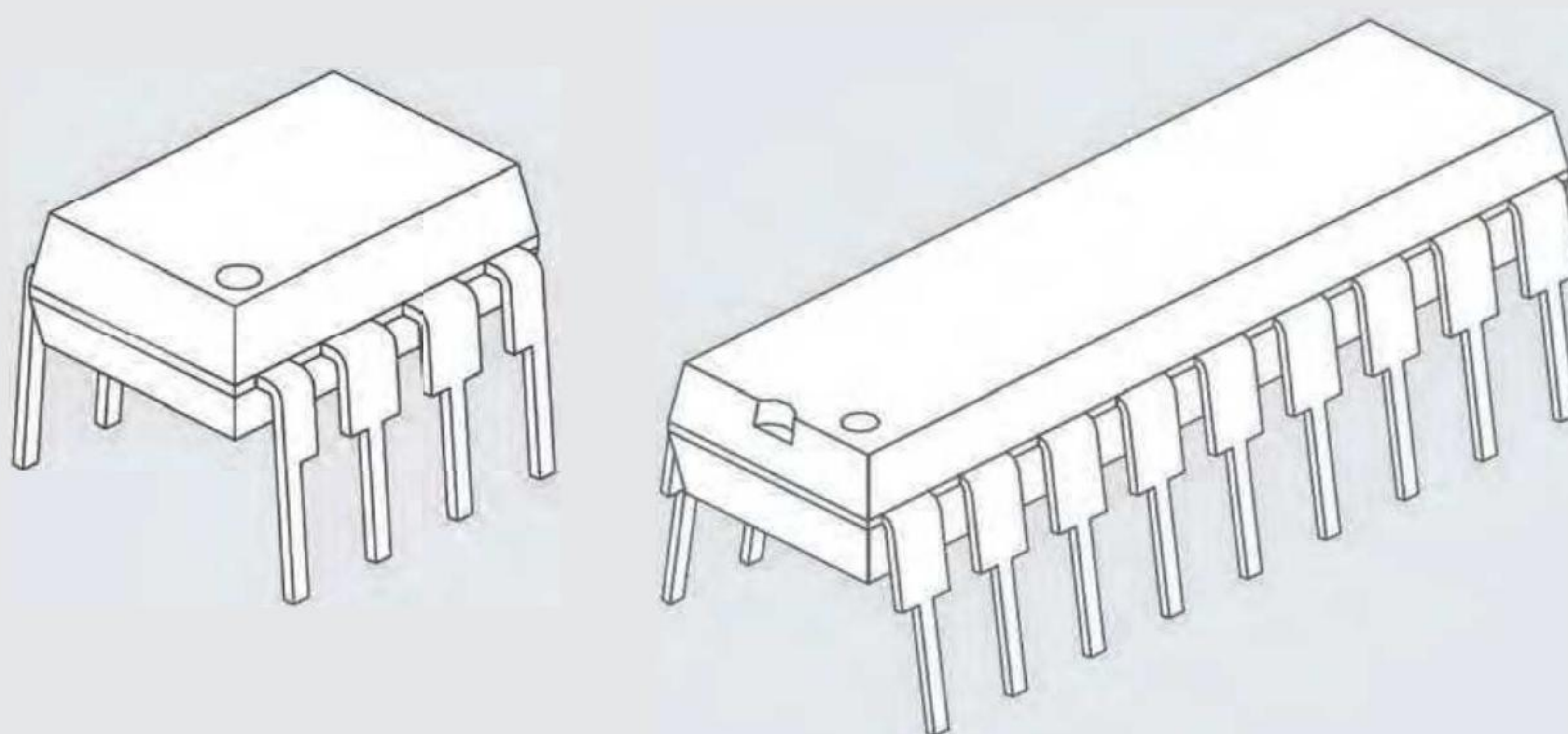
Final thoughts

While this *Audio Spectrum Analyser* is not a particularly 'useful' design, it's certainly been very educational, great fun to play with, and generated a lot of interest at our local Maker Faire, as the LCD danced to music and voices. With the inclusion of software libraries for graphics and text display, it offers building blocks for other projects, even unrelated to audio. We are already planning a bedside alarm clock for the version 2 hardware!

The software, PCB and 3D printer enclosure files are all available on the magazine website. The PCB can be ordered from the *PE PCB Service* or directly from PCBWay, at this webpage: <http://bit.ly/pe-may20-pnm>

This project has spanned two years, and we hope you have enjoyed the journey and the results. If you take this design and create something new, do tell us!

Need a programmed PLC for your Practical Electronics project?



Coming soon from the Practical Electronics online shop at:
www.electronpublishing.com

Make it with Micromite

Phil Boyce – hands on with the mighty PIC-powered, BASIC microcontroller

Part 16: Introduction to the Micromite Robot Buggy

This month, we begin a really fun project – the *Micromite Robot Buggy (MRB)*. The whole idea behind this robot is to demonstrate how to bring together many of the lessons learnt so far in the *Make it with Micromite (MIWM)* series, and combine them into a fun, highly customisable project. To help minimise the overall cost of the robot, three important design criteria were set:

1. Use the *MKC* as the robot brain – all aspects of the robot will be programmable, and under the control of MMBASIC code.
2. Use the Bluetooth module to provide a wireless link between the *MKC* and your terminal app.
3. Enable plug in of any other *MIWM* module from the series to provide extra features at no additional cost.

The *MRB* could be regarded as a mobile *MKC*; but for the *MKC* to become mobile, some additional hardware is needed. For example, a minimum of two motors, a set of wheels, and some form of battery power.

This month, we will start discussing a new module: the robot chassis. This will not only provide the new hardware required, but also allow the *MKC* and other *MIWM* modules to be plugged in.

The robot chassis module comprises two main parts: an acrylic chassis unit (for attaching the mechanical hardware), and a daughterboard (for mounting the electronics). By simply plugging in your *MKC*, Bluetooth module and TFT module, along with a basic test program, you will create the *MRB* shown in Fig.1.

Background

The design of the *MRB* was inspired by the versatile Pololu Zumo robot. The Zumo is popular with Arduino users thanks to the availability of a Zumo shield (which enables an Arduino to be directly inserted). The Arduino then controls all aspects of the robot.

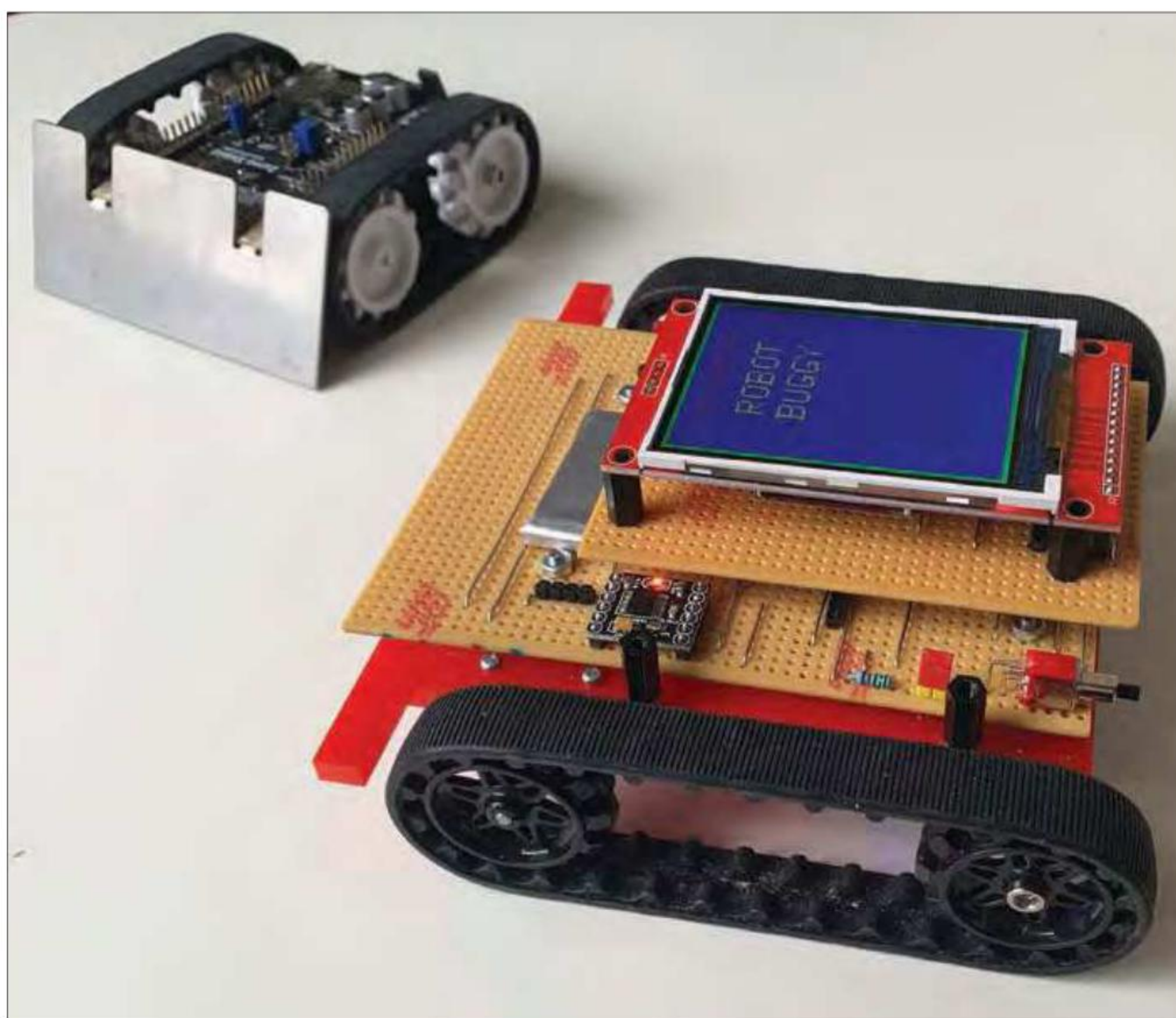


Fig.1. The *Micromite Robot Buggy (MRB)* (front) next to the popular Zumo buggy, on which the design is based. Note the red acrylic chassis under the stripboard.

The Zumo is a small (100mm × 100mm) robot that uses a pair of silicone tracks to provide traction. It is a very modular design, with all mechanical and electrical elements available as individual parts. Therefore, the Zumo seemed like a suitable robot from which to create a Micromite-controlled version.

Initially, I considered replacing the Arduino Zumo shield with an equivalent Micromite daughterboard, and mount this onto the existing Zumo chassis. The Micromite daughterboard should ideally be a piece of stripboard using through-hole components and modules, making it a quick project for this series. However, early prototypes of the Micromite version quickly highlighted the fact that in order

to physically accommodate the *MKC* (and other modules from the *MIWM* series), a slightly bigger chassis would be required. This would mean that we could no longer use the readily available Zumo chassis. This wasn't too much of an issue because the Zumo chassis could easily be replaced with an alternative. Access to a laser cutter meant I could create a custom acrylic chassis designed to meet our exact requirements. The end result is only slightly larger (150mm × 150mm) and is shown in Fig.2.

Replacing the Zumo chassis with our own custom chassis meant that two other matters needed resolving. This is because the Zumo chassis has appropriately sized (small) tracks, and also has a built-in



Fig.2. This custom laser-cut acrylic chassis is used instead of the smaller Zumo chassis.

battery compartment designed to take four AA rechargeable batteries. So we need to resolve design issues around tracks and power.

The silicone tracks need to be increased in size to suit our bigger chassis. In fact, all that is required is to increase the distance between the wheels (easy), which means slightly longer tracks. On the Zumo, each silicone track has 22 ‘teeth’ and it is wrapped around a pair of toothed-wheels (the wheels and tracks are available as a kit). The track length ultimately defines the distance between the wheel-centres and on the Zumo this equates to a spacing of 48mm. Thankfully, there is an alternative kit available which has tracks containing 30 teeth (30T, see Fig.3). This simply means that the tracks are slightly longer than the Zumo version, and they result in the wheels being spaced 85mm apart. This is perfect for our new chassis, so these 30T tracks are used in our robot. You can see the increased wheel spacing and the longer tracks in Fig.4.

Power

Now we turn to power for the robot. Initial prototypes were designed to use a readily available mobile phone USB battery pack. These can supply the 5V output required to power the robot; however, an unforeseen problem was that 99% of these units are designed to automatically switch off if they are not connected to a ‘load’ (ie, not connected to a phone). The current consumption of the Micromite falls well below the battery pack’s



Fig.3. The 30T track and toothed wheels are available as a kit (Pololu #3033).

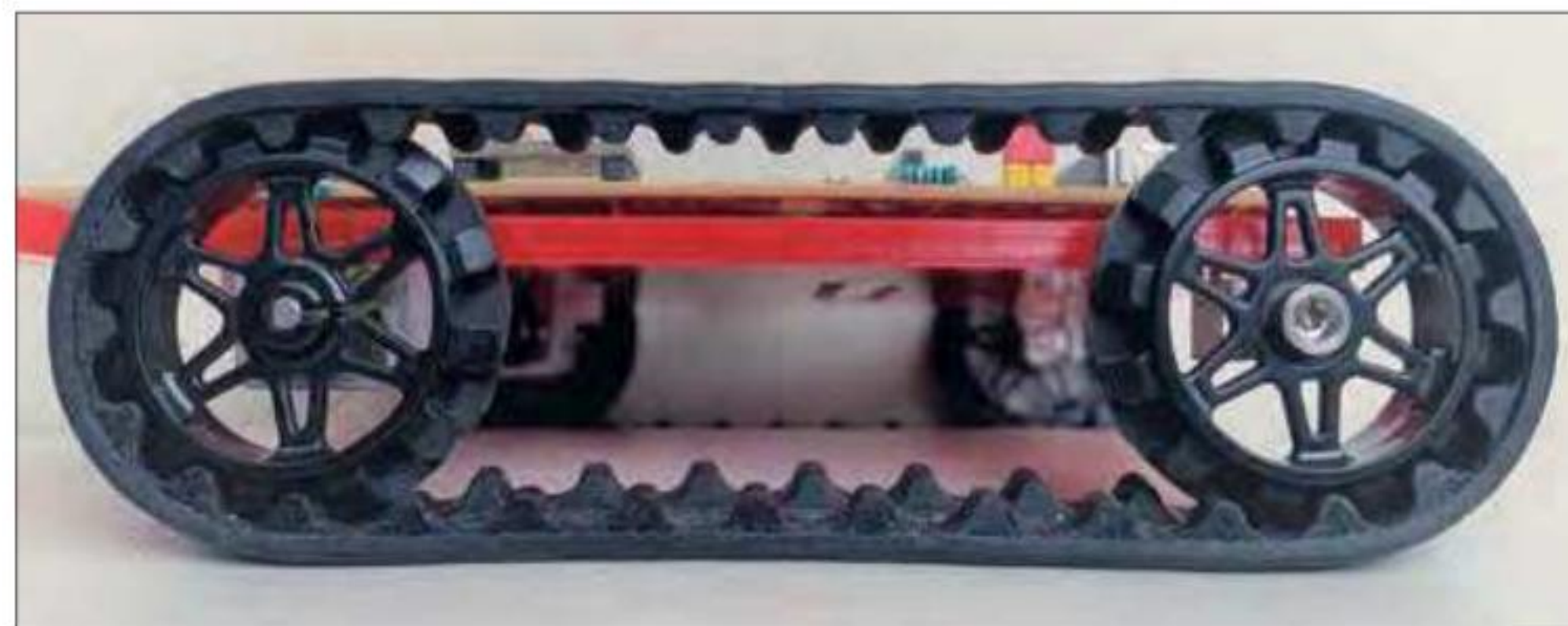


Fig.4. The shorter Zumo tracks have 22 toothed-slots designed to be used with wheels spaced 48mm apart. The MRB uses the longer 30-toothed tracks allowing the wheel spacing to be increased to 85mm.

threshold and hence it would automatically switch off after just a few seconds. All kinds of ‘dummy loads’ were tried (LEDs worked the best) but then a new issue arose – how to turn the robot on and off, especially if the battery pack’s on/off button was inaccessible. The battery pack also needs to be recharged, requiring access to its charging socket, which means it would need to be easily removed from the robot. Furthermore, most battery packs are physically bigger (thicker) than we want, so the decision was taken to abandon this idea, and instead use a thin LiPo battery (Fig.5), partnered with a PowerBoost 1000C module from Adafruit (Fig.6). This excellent module not only takes the LiPo voltage (typically 3.7V) and boosts it to 5.2V, it also has a dedicated LiPo charger onboard to recharge the battery without ever needing to have direct physical access to it. An enable pin (EN) on the module provides the ability to switch the 5.2V boosted output on and off. With a little design imagination we can use a push button (instead of a switch) to turn the robot power on; and then use program-code to turn the power off – more on this next month.

So, in summary, by using a custom acrylic chassis, the longer 30T tracks and a LiPo battery (along with the Adafruit booster/charging module), we can replace the Zumo chassis with our own bespoke design.

Building-blocks overview

We explained above that to create the MRB, several new parts (mechanical and electrical) are brought together along with some existing *MIWM* modules. The way these building blocks work together is summarised in Fig.7. To make things a little simpler to follow, the diagram is laid out to mimic the actual physical locations on the robot itself.



Fig.5. A typical 2-wire LiPo battery is both thin and lightweight making it suitable for our robot. Ensure a minimum capacity of 2000mAh, and that the leads are terminated in a 2-way JST connector as shown here.

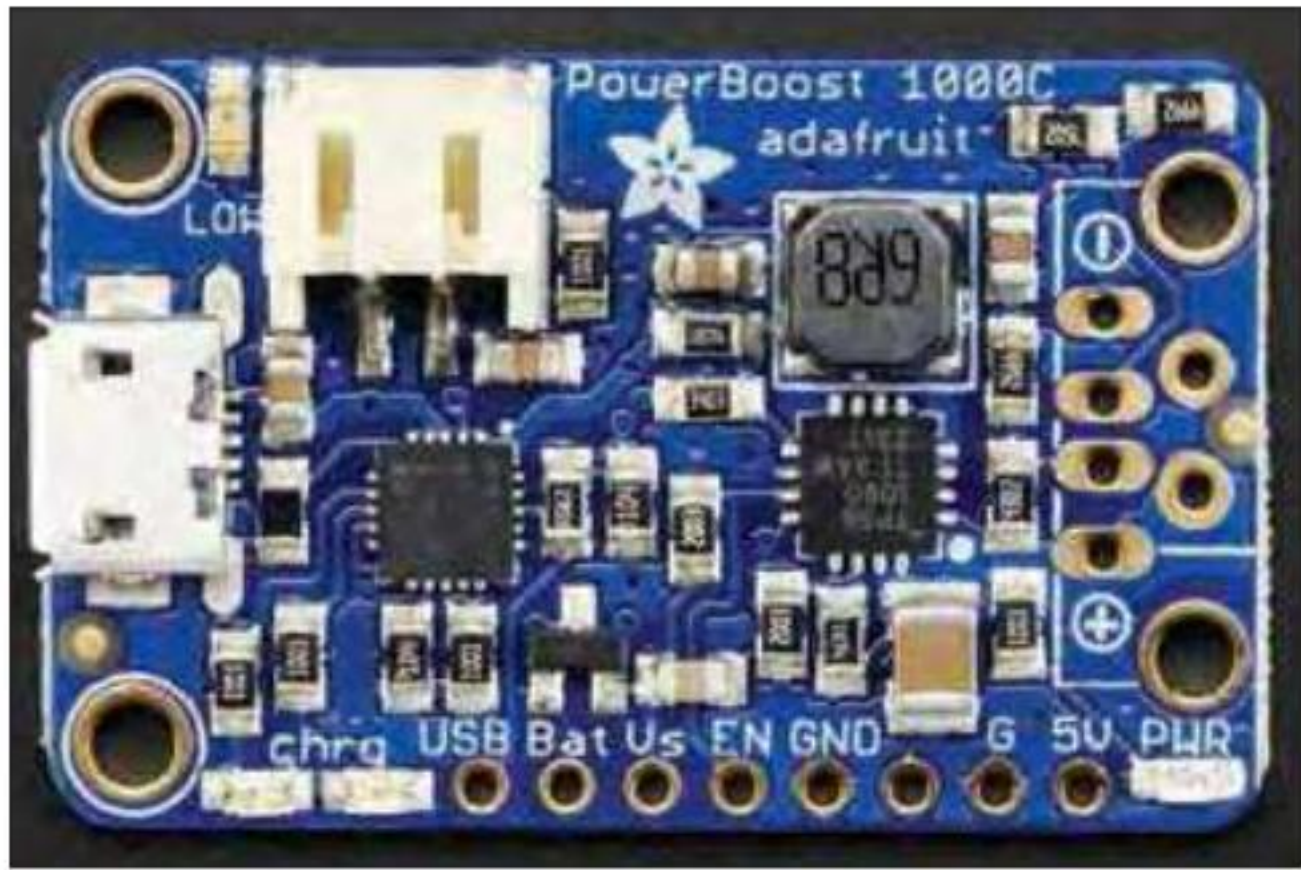


Fig.6. The Adafruit PowerBoost 1000C module contains all the battery management circuitry allowing a LiPo battery to power our robot.

Note that each building block falls into one of three distinct categories, colour coded as follows:

- New elements associated with the acrylic chassis are shown in red (mainly the mechanics of the wheels)
- New elements associated with the daughterboard are shown in blue (all the new electronics associated with power circuit, and the motor-driver)
- Existing modules from the *MIWM* series are shown in grey.

Fig.7 shows that the laser-cut acrylic chassis is used as a baseplate to which the following items are attached:

- Two motors (Fig.8)
- Two motor mounts (Fig.9)
- Two wheel mounts (Fig.10)



Fig.8. A Pololu micro metal gearmotor. The prototype uses a 6V, 75:1, LP, extended shaft (#2209).

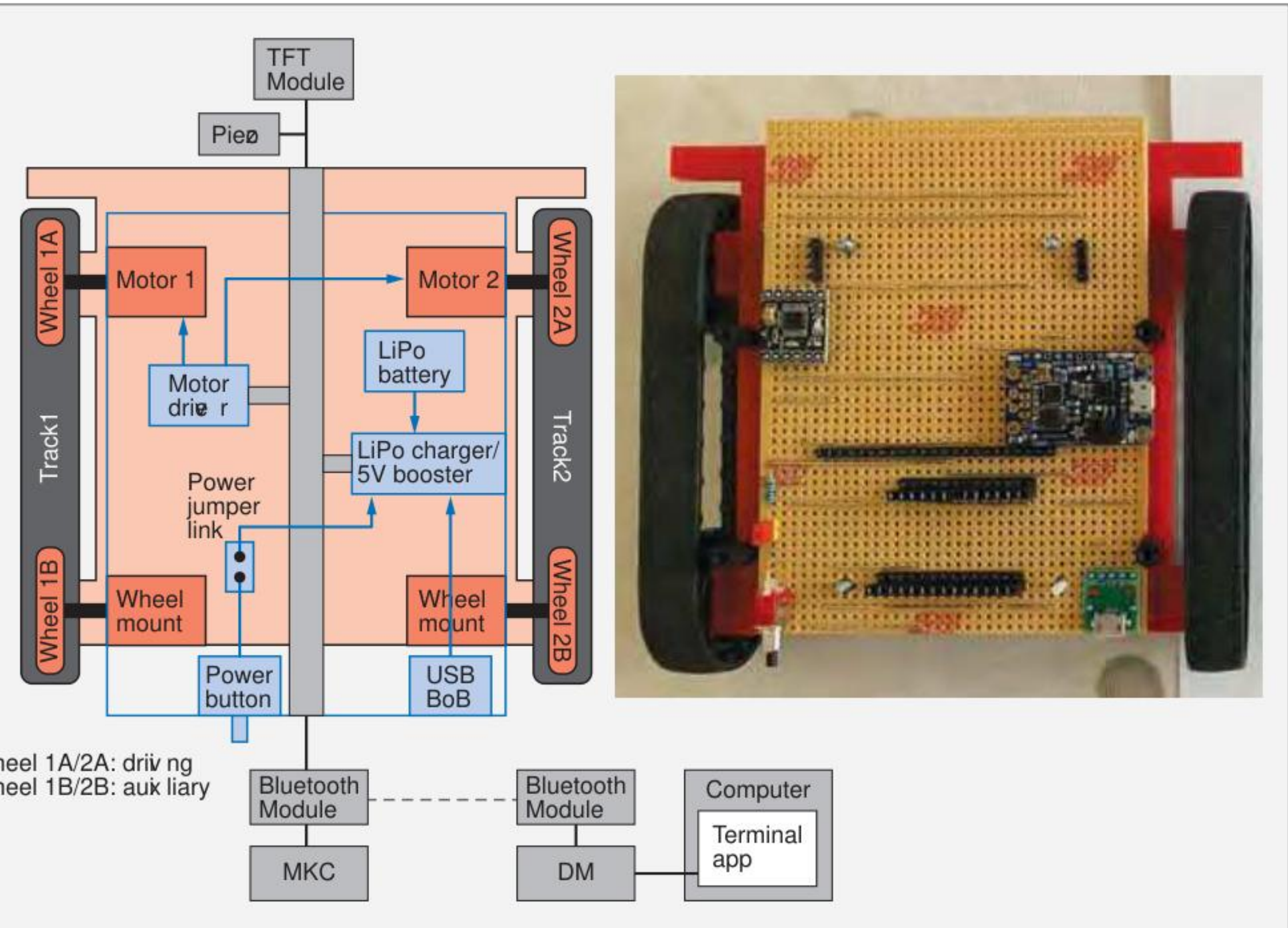


Fig.7. Block diagram of the *Micromite Robot Buggy*. The chassis and daughterboard contain all the new parts, and also allows the *MKC*, and existing modules, to be plugged in.

- Four toothed wheels and two tracks (Fig.4)
- The daughterboard.

Incidentally, the first prototype of the *MRB* had the motors and wheels attached directly onto the stripboard (ie, mounted onto the daughterboard). However, there was too much flexing of the stripboard; it just didn't have the required rigidity to keep the wheels in place and the tracks suitably tensioned. Hence the all-in-one chassis/daughterboard/stripboard idea was abandoned and replaced by the 'chassis plus daughterboard' concept.

The daughterboard is a piece of stripboard (fixed to the chassis) with the following items/modules attached:

- LiPo booster/charger module (the Adafruit Powerboost 1000C module) (Fig.6)
- Micro USB BoB (breakout board – see Fig.11). This provides a conveniently located USB socket from which to charge the LiPo (via the Adafruit module)

- Power button (Fig.12) (plus pull-down resistor and power-link). These control the EN pin on the Adafruit module
- Motor-driver module (Fig.13) (an H-bridge interface allowing motor control from the Micromite I/O pins)
- Pins and sockets (Fig.14) positioned in a precise manner making it easy to plug everything together, as detailed here:
 - Pins for the *MKC* and Bluetooth module to be plugged in (from below)
 - Sockets for a *MIWM* module to be plugged in from above (such as the TFT module)
 - A pin and socket pair for each motor (allows for easy assembly/disassembly of the daughterboard from the chassis)
 - Header pins for attaching the 'SMD' modules (Adafruit, motor driver, USB BoB).

All of the above will be discussed in more detail, but you should be able to make reasonable sense of the block diagram in Fig.7. Your existing *MKC* is being upgraded to having a set of wheels and a battery. The wheels will need to use four low-power I/O pins on the Micromite and these are connected to the input of a motor driver module. The motor driver then outputs the higher power required to operate the motors. The battery circuit also uses an I/O pin and this is used to switch the robot power off (with the pushbutton turning power on). All power functionality is managed by the LiPo booster/charger module which simply ensures 5.2V power is supplied to the robot from the rechargeable LiPo battery whenever the robot is turned on. To recharge the LiPo, a 5V charger can be plugged into the USB BoB.



Fig.9. (left) Micro metal gearmotor (extended) bracket kit (Pololu #1089) and Fig.10. (right) Two M3 threaded mounting brackets are used to fix the 'auxiliary' wheels to the chassis.



Fig.11. (above) A USB BoB is utilised in order to conveniently locate the LiPo charging socket.



Fig.12. (right) A miniature push-to-break button is used to turn on the LiPo booster and hence deliver power to the robot.

Motors, wheels and tracks

In Fig.7, you can see a pair of wheels, a silicone track and a single motor, positioned on each side of the robot. The two motors used in our robot are referred to as ‘micro metal gearmotors’ and as the name implies, they contain a gearbox (fixed ratio) made from metal – as shown in Fig.8. The gearbox gives the motor more torque than a standard motor – something that is useful in any robot. The motors operate from 6V DC, applied to a pair of contacts located on the non-gearbox end of the motor (see Fig.15). As with any standard DC motor, reversing the voltage will reverse the spin on the motor. Note that in our design, we are driving the motor at approximately 5.2V, which is still enough to provide a decent amount of torque. Each motor is fixed to the chassis by means of a motor mount, as shown in Fig.16. One wheel in each pair is attached directly to the motor’s

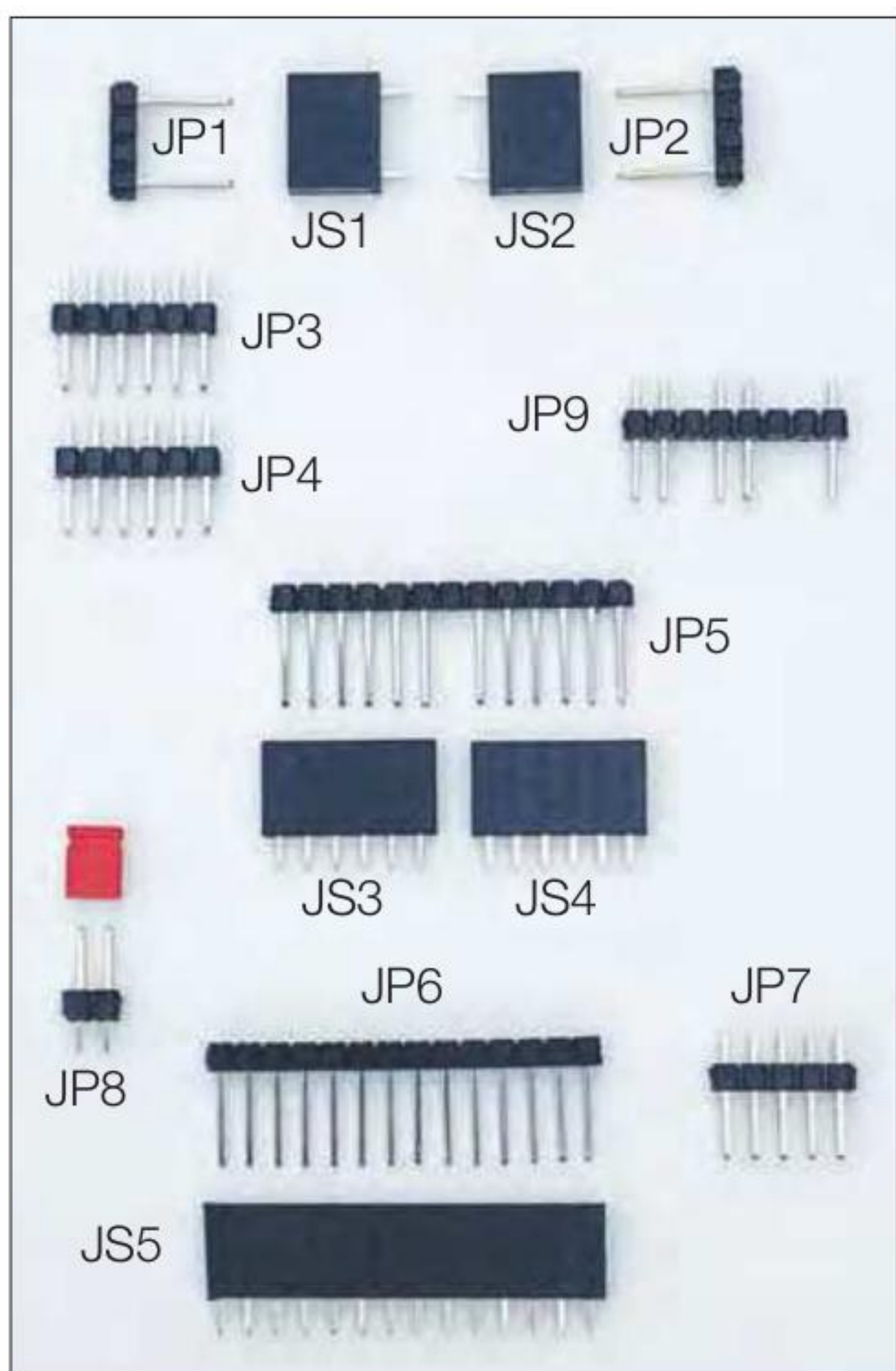


Fig.14. A complete set of connectors used in the robot buggy. Ensure you modify the connectors to match them as they are shown here.

shaft and this is referred to as the ‘driving’ wheel. The other wheel is referred to as the ‘auxiliary’ wheel and is free to spin on a spindle (Fig.17). The spindle simply screws into a wheel mount (Fig.10), which in turn is fixed to the chassis. A silicone track is positioned around the pair of wheels with enough tension so that when power is applied to the motor, it turns the driving wheel, which in turn rotates the track around the auxiliary wheel (Fig.4).

This setup is repeated on the other side of the robot to provide the traction for movement. Driving both motors in the same direction will result in the robot moving in one direction, and reversing the voltage to both motors will move the robot in the opposite direction. To turn (or rather, to ‘spin’) the robot, one motor is driven in one direction, and the other motor in the opposite direction. Reversing the voltages will cause the robot to spin in the opposite direction.

Motor choice

A point to bear in mind is that the quality of the motor is very important when used in a project such as this. If you do an online search for ‘micro metal gearmotor’, you will see that there are many variants to choose from, and prices will range from around £5 per motor, to approximately £25 per motor. A really good reference guide to these motors can be found on the Pololu website, so can I recommend that you take a look: <http://bit.ly/pe-may20-pololu1>

Choosing the wrong motor type will cause problems, so I will cover four high-level points to help you choose right one:

1. These motors are available in two voltage options, 6V and 12V. Ignore the 12V ones – we need the 6V version.
2. Two shaft lengths are available, ‘normal’ (single shaft), and ‘extended’ (dual shaft). The extended type (see Fig.15) allow for a shaft encoder disc to be mounted on the back of the extended motor shaft (visit: <http://bit.ly/pe-may20-pololu2>). The encoder disc (magnetic or optical) can then be used with additional



Fig.15. Close-up of the modified 4-way socket soldered to the motor contacts. Note the motor contact marked with ‘+’ needs to be to the left when in the motor mount. Here the ‘extended’ shaft can be seen protruding out the back of the motor.



Fig.13. The motor driver module is based on the 2-channel DRV8833 H-Bridge IC.

hardware (a sensor) to provide a stream of output pulses for each revolution of the motor. By counting the pulses, the number of revolutions can be counted and hence the speed of the motor can be inferred. This feature is not currently implemented in our design; however, we may add it at a later date. There is only a small price difference between the normal and extended shaft types, so we would recommend opting for the extended type. That said, the normal type is absolutely fine to use.

3. Four power variants are available: low (LP), medium (MP), high (HP), and high with carbon brushes (HPCB). This is the one parameter that really affects the price of the motor. We used the cheapest LP motors in our prototype and they worked just fine. However, the more power you can afford, then the more torque your robot will have. The carbon-brush option is not a requirement.
4. The gear ratio is the final (but most important) parameter to consider. You will see figures quoted between 5:1 and 1000:1. The lower the ratio, the faster your robot will move – however, its driver shafts will deliver less torque (or put another way, it won’t be able to move as much weight). The ideal ratio for our robot is somewhere between 50:1 and 100:1. In our prototypes we have typically used 75:1.

The above has given you an idea as to what can be used, but if you’re a little overwhelmed with the number of choices, then I suggest using two: 6V, 75:1, LP or HP, extended (dual) shaft motors. LP or HP depends on your budget and/or the supplier’s availability.

Parts list and next month

That just about wraps it up for this month. Next month, we will look at assembly and the electronics involved. In the mean time, have a look at Table 1 to see a complete list of all the parts required to build the robot chassis module. Most of the items are referenced to the various photos throughout this article to assist with identification and



Fig.16. Fixing the motor and motor-mount bracket (shown here mounted on an off-cut chassis). Left to right: a) Motor gearbox sits into slots; b) Place nuts into bracket ‘wings’; c) Screw onto chassis from the other side.

assembly. The majority have already been mentioned already in the text; however, there are a few other parts required that will come up in the assembly guide. For example, some nylon nuts and bolts used for attaching the daughterboard to the acrylic chassis. You may already have some of the items in the list; if not, they should be easy

Questions? Please email Phil at:
contactus@micromite.org

enough to source through the Internet. Online UK suppliers such as Cool Components, PiHut, Pimoroni, Hobby Components, and Rapid Electronics are worth visiting for the items that may be more specific (I have no affiliation with any of these – but I am a regular customer of them all thanks to the useful product range they stock). If you prefer a one-stop-shop, then as usual, **micromite.org** will offer various options including the custom laser-cut acrylic chassis.



Fig.17. CAD drawing showing how to attach the ‘auxiliary’ wheel with the supplied spindle, washer, and nut. (Note: in our design, the generic blue ‘robot chassis’ shown here is actually the motor mount – see Fig.10.)

Table 1: Parts list for the robot chassis module. You will also need a length of wire to complete all the all wire-links (1m is enough)

Qty	Fig	Part No	Description	Comments
1	Fig.2		Acrylic chassis	Laser-cut (from micromite.org)
1	Fig.3		30T track & wheel kit	Tracks, wheels, spindles, washers + nuts (Pololu #3033)
1	Fig.5		LiPo battery	Minimum 2000mAh (with 2-way JST connector)
1	Fig.6	MOD3	LiPo charger/booster	Adafruit PowerBoost 1000C
2	Fig.8		Micro metal gearmotor	various options - see text
2	Fig.9		Motor mount kit	Brackets, screws + nuts (Pololu #1089)
2	Fig.10		Wheel mount	M3, metal (from micromite.org)
4			12mm M3 nylon screw	
8			M3 nylon nut	
1			Stripboard	50 holes x 36 tracks (typically 95mm x 127mm)
1	Fig.11	MOD2	micro USB BoB	(from micromite.org)
1	Fig.12	S1	Push-to-break button	Multicomp MC8MS8P1B06M7QES (from micromite.org)
1		R1	10kΩ pull-down resistor	
1	Fig.13	MOD1	Motor-driver module	DRV8833 (from micromite.org)
1	Fig.14	JP8	2-way pin strip + jumper-link	
2	Fig.14	JP1, JP2	4-way pin strip (modified)	For motors
1	Fig.14	JP7	5-way pin strip	For USB BoB
2	Fig.14	JP3, JP4	6-way pin strip	For motor driver module
1	Fig.14	JP9	8-way pin strip (modified)	For LiPo charger/booster module
1	Fig.14	JP5	13-way pin strip (modified)	For connecting MKC/BT module
1	Fig.14	JP6	14-way pin strip (modified)	For connecting MKC/BT module
2	Fig.14	JS1, JS2	4-way socket (modified)	For motors
2	Fig.14	JS3, JS4	6-way socket	For plugging in MIWM modules
1	Fig.14	JS5	14-way socket	For plugging in MIWM modules

AUDIO OUT



By Jake Rothman

Noise about noise – a new slant on analogue noise with tilt control – Part 2

Last month, I introduced my analogue noise generator. This month we will build it, examine its 'tilt control' and create a variety of interesting noise-generator-based synthesiser circuits.

Tilt tone control

I recently described a Baxandall tone control in *PE (EPE)* April and May 2018 and I thought this would be a suitable place to introduce an intriguing variant of this design, the tilt control. Conceived by R Ambler (*Wireless World*, March 1970) and later adopted in the Quad 34 pre-amp, this circuit combines Baxandall's bass and treble controls into a single control.

This control is flat when the pot is centred and the frequency response pivots around a mid-point to give boosted treble and cut bass when rotated fully clockwise. When fully anti-clockwise it has the reverse effect of maximum bass boost and maximum treble cut. At intermediate settings of these positions it can give a gentle slope or tilt across the whole audio frequency range. A centre-detent/click pot is ideal if you can get one. Tayda do a 20k Ω one with a W-law (A-1959). To use this, re-scaling of the component values

would be required: C4 and C7 would be 5.6nF, R9 and R10 become 4.7k Ω , and R8 and R13 are set to 16k Ω .

If the control is set to give a downwards tilt, it can be used to give the white noise a pink noise approximation. In theory, this should be -3dB/octave, which needs a more complicated filter, but this tilt control gives a reasonable sonic impression for most musical uses. On full treble tilt it gives a harsh 'blue' noise suitable for high-hats and transient sounds. Turned the other way, it gives a lowish roar good for tom-tom sounds. The tilt control circuit is shown in Fig.12; on the PCB this is combined with the noise source in Fig.8 (last month). The frequency response is shown in Fig.13a. Note the pivot-point is 2.5kHz, which gave the best synth effects with the noise. Fig.13b shows the effect of different pot positions.

Component list (for the synthesiser version)

Semiconductors

IC1 TL062 or MCP6002 low-power op amp. For Hi-Fi, use TL072 or a better Bi-Fet (dual) op amp
REG1 TL431

Resistors (all 0.25W 5% carbon-film)

R1, R2	2.2k Ω
R3	22k Ω
R4	27k Ω (only for 9V or greater power supply)
R5	1.5k Ω
R6	56k Ω
R7, R15	100k Ω
R8, R13	33k Ω
R9, R10	10k Ω
R11 (VR1)	50k Ω lin 16mm vertical PCB mount pot.
R12	560k Ω
R14	100 Ω

Capacitors

Dielectric type not critical: ceramic, polyester, electrolytic or tantalum can be used. All 5mm pitch radial. Scale voltage rating according to power supply. If using standard 5V use minimum 6V rating.

C1	100 μ F
C2	47 μ F
C3	22 μ F
C4, C7	2.7nF (for Hi-Fi 1kHz turnover use 6.8nF polyester)
C5, C6	470nF
C8	10 μ F
C9	4.7 μ F

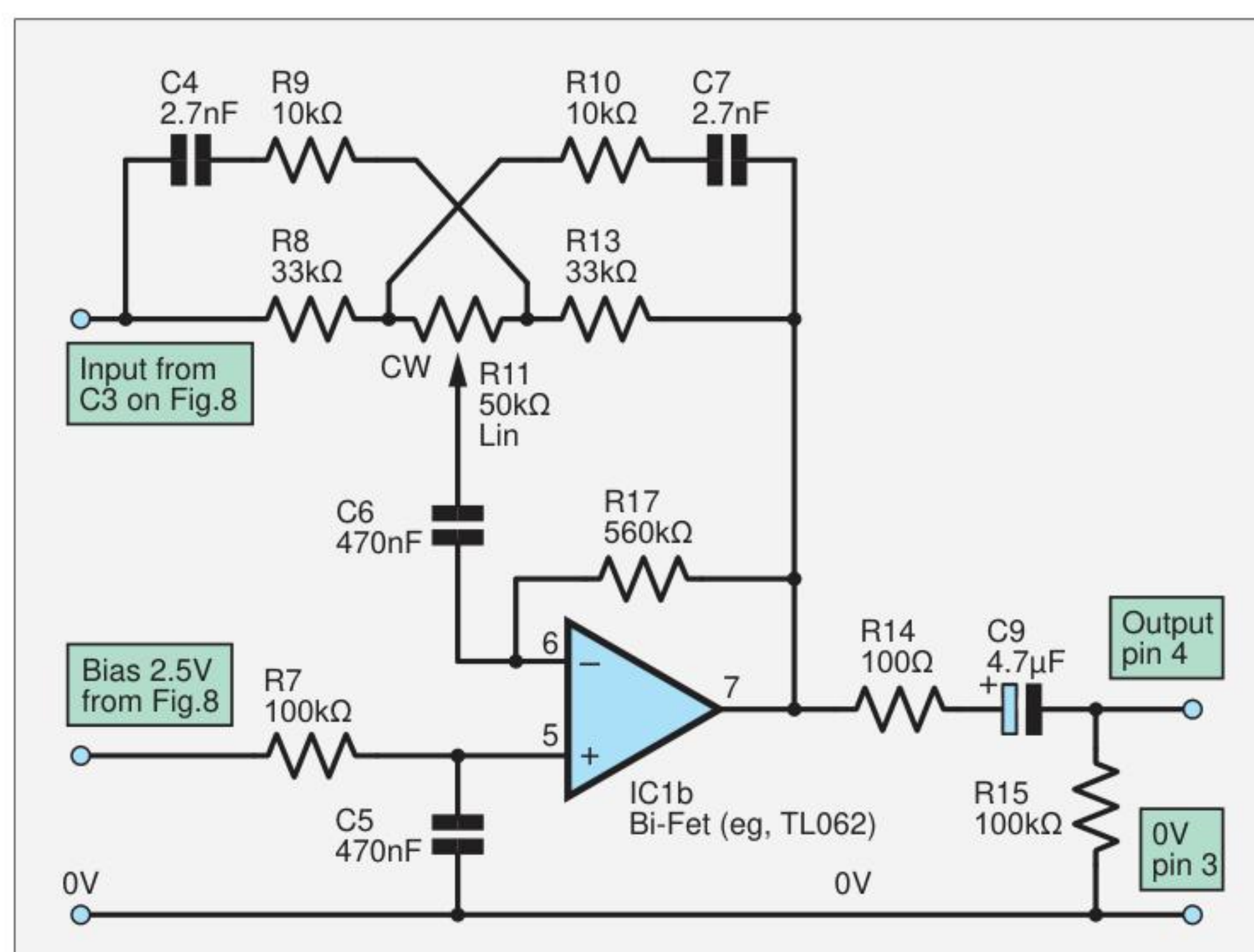


Fig.12. Tilt tone control circuit: this can be thought of as cross-coupled Baxandall bass and treble controls combined in one.

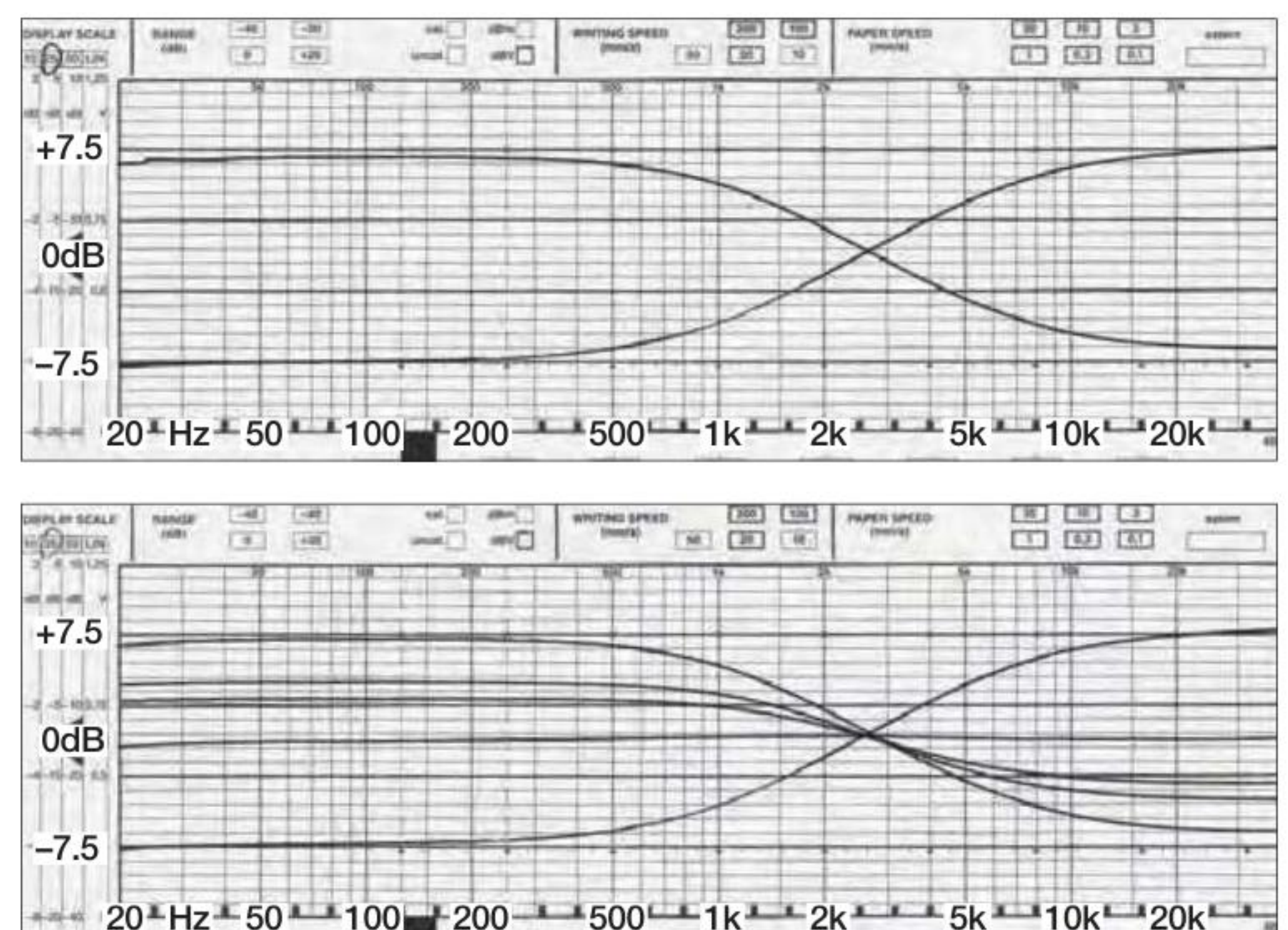


Fig.13a. (top) Frequency response of tilt tone control; the 'pivot' point is 2.5kHz. Fig.13b shows the effect of different pot positions.

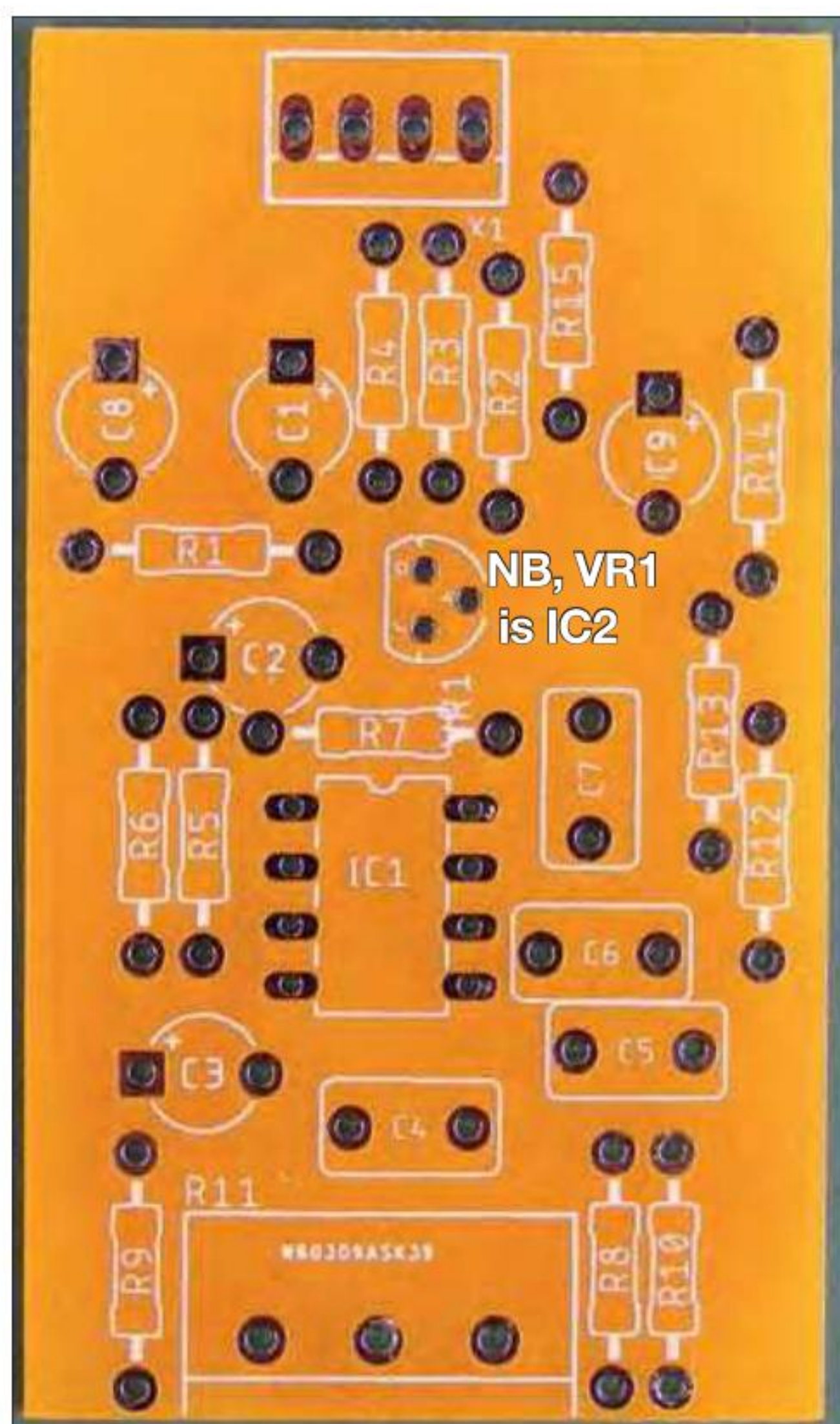


Fig.14. PCB overlay for combined noise generator and tilt control Fig.8 and Fig.12).

Miscellaneous

PCB and 4-pin Molex 0.1-inch connector assembly.

PCB

The PCB overlay is shown in Fig.14 and the track layout in Fig.15. Since the design is single-sided it is suitable for home etching. Eagle files and PCBway ready-made PCBs will be available from the *PE* site and shop as usual. I still get my single-sided boards made at PCBway because of the greater joint reliability afforded by plated-through holes. The finished board is shown in Fig.16. It is small enough to be mounted by means of the pot shaft, but support at the back is needed if the unit is to be moved around.

Hi-Fi tilt control

Here's a bonus circuit! This design can be adapted for Hi-Fi use by leaving off

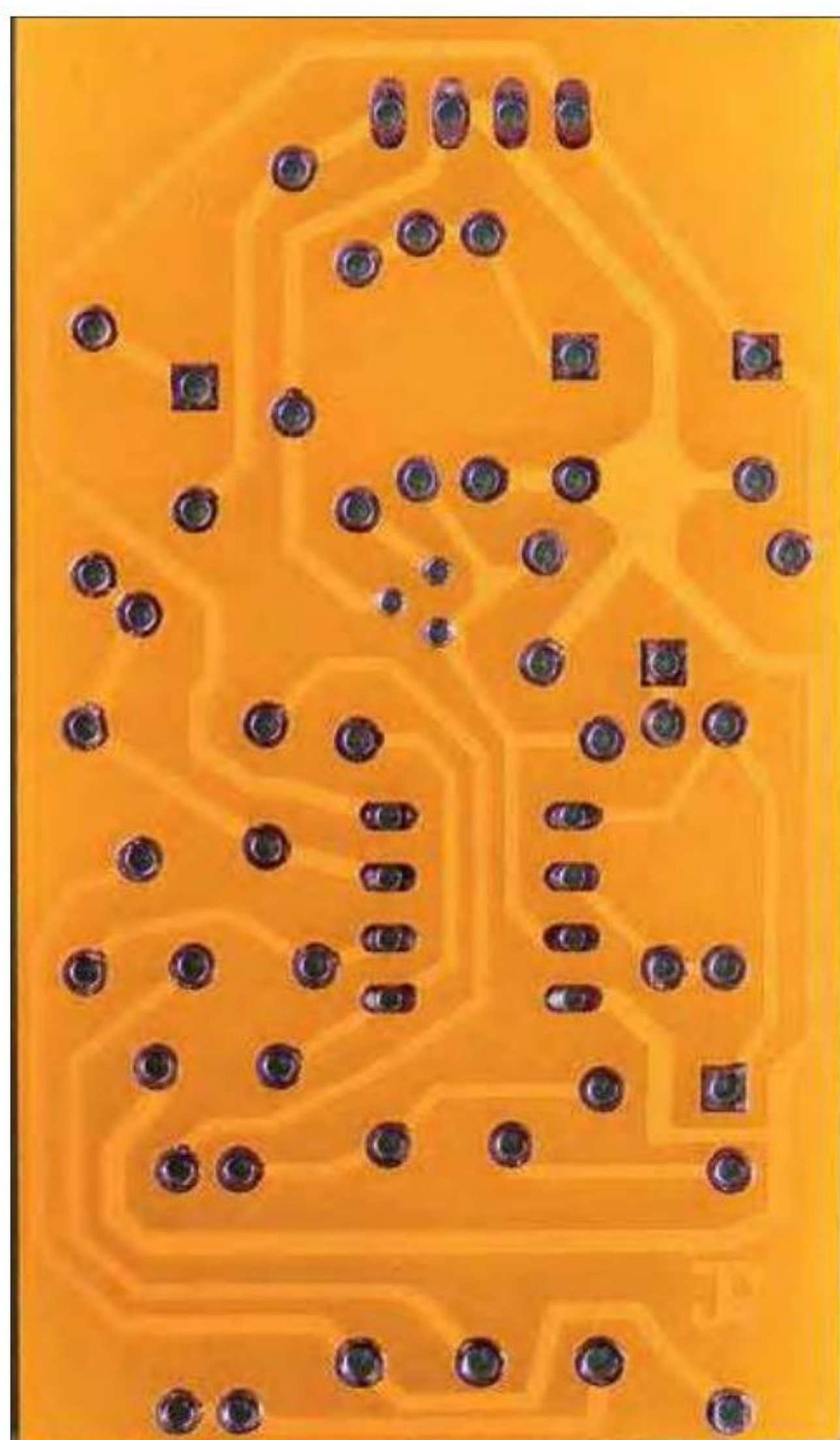


Fig.15. PCB track layout. This is single-sided, so easy to etch.

the noise generator components and constructing the circuit shown in Fig.17. The pivot point should be moved to the standard Baxandall value of 1kHz, as shown in Fig.18. This is done by multiplying the 2.7nF frequency-determining capacitors C4 and C7 by 2.5 to give 6.8nF. If you are using the 20kΩ centre-click pot, use 15nF and change resistors R8, R9, R10 and R13 as previously mentioned. Note the noise generator part of the circuit has to be rejigged to become a bias generator. Also, the first op amp stage is reconfigured to be inverting to ensure there is no overall phase inversion. (This is because the tilt circuit is inverting). The op amp used should be changed to an audio-quality device, such as a TL072 and the resistors to metal-film types. The resistors, pot and capacitors could all be scaled to a lower impedance (capacitors multiplied by 10 and resistors divided by 10) and a



Fig.16. The finished noise module. Oops I forgot the mounting holes at the back!

NE5532 op amp used to further reduce noise and distortion. The power supply should be upped to say 24V to give reasonable headroom. Finally, Fig.19 shows the PCB constructed as a tilt-control-only circuit. The pot can be replaced with a dual-gang version for stereo use.

The 1980s, the decade of analogue noise-based music synthesis

The classic analogue drum sound with noise was popularised by the Simmons SDS-3 syndrum, familiar to many UK readers as the tom-tom beats at the beginning of the old theme tune to the BBC soap *East Enders*. This sound was generated by adding a short duration

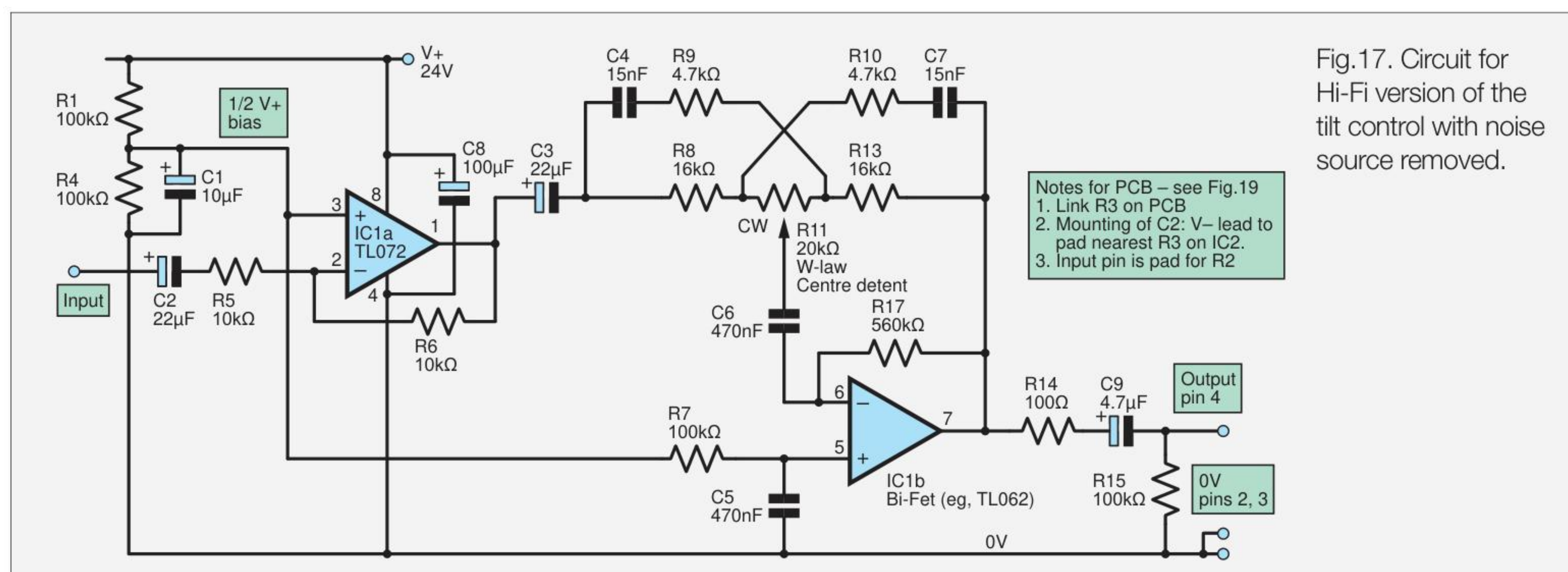


Fig.17. Circuit for Hi-Fi version of the tilt control with noise source removed.

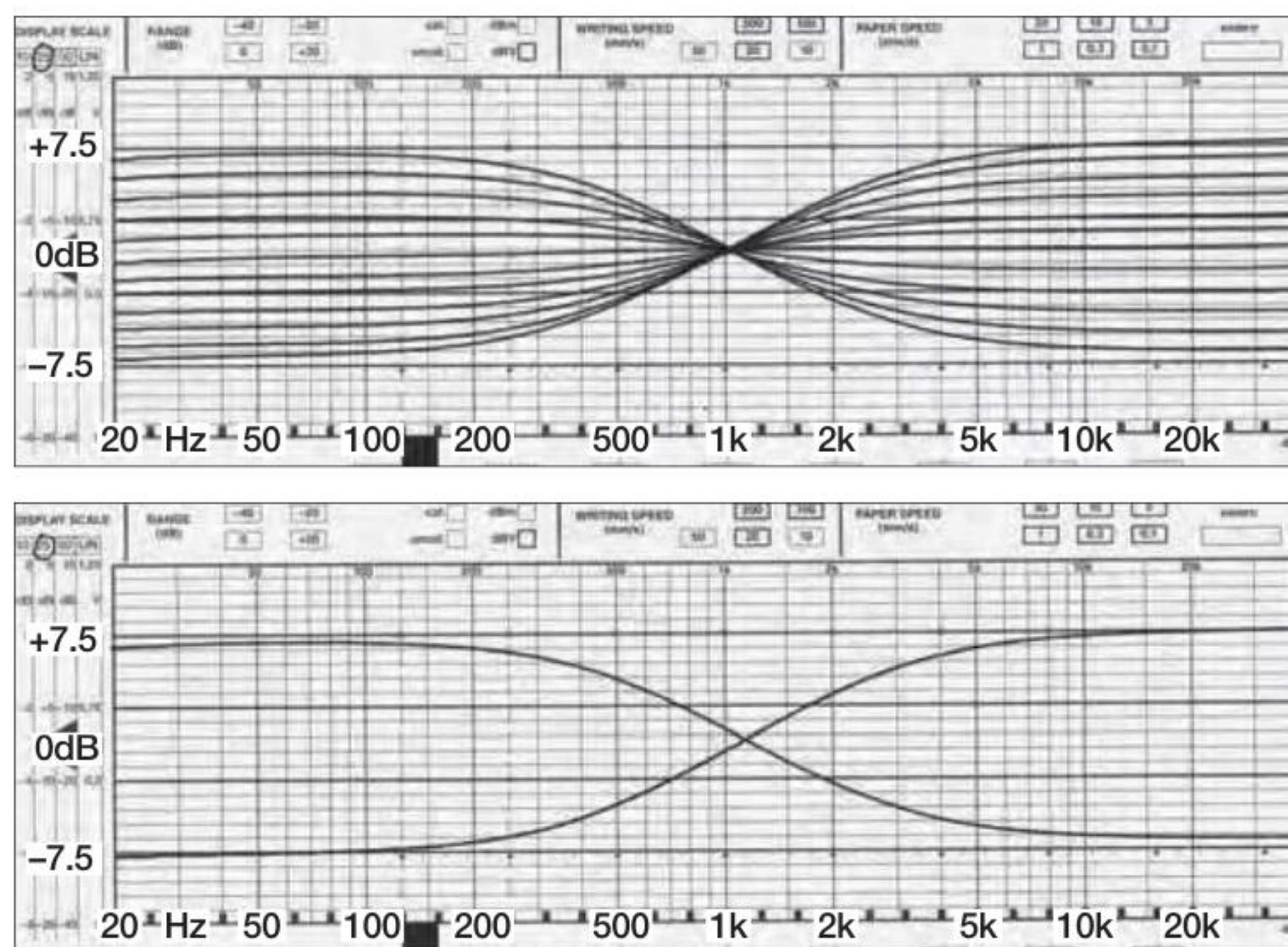


Fig.18a. (top) Frequency response of the Hi-Fi tilt control with almost all possible pot positions. Pivot point now the standard 1kHz, using a 20kΩ W-law pot with 15nF frequency-determining capacitors (C4 and 7). Fig.18b shows the response with a 50kΩ lin pot and 6.8nF capacitors, a little higher at 1.2kHz. If 7.5nF caps can be obtained it would be nearer the desired 1kHz.

burst of white noise to the start of a filtered decay of a triangle waveform with a bit of downwards pitch bend as the sound decays. Occasionally, the noise had its own envelope and VCA for snare sounds, but it was often sufficient to just mix the noise with the main waveform. The leading edge of the trigger pulse was often also mixed in to give the initial transient hit. Usually, the trigger signal came from a piezo ceramic disc glued to a piece of wood which was struck. Maplin offered some kits called the Syntom and Synwave (published in *Electronic and Music Maker* in April and July 1981) which used these tricks. Putting the two together made a plausible Simmonds imitator. Building loads of them helped fund my student digs at the time. The basic block diagram is shown below in Fig.21. I suspect it's only a matter of time before the Syntom is resurrected to replace the Theremin as the new hipster musical toy.

Vinyl scratch simulator

I think it's fun to make pristine digital recordings sound like vinyl records. This is necessary for giving a vintage sound effect for films and animations. Of course, scratch noise is a

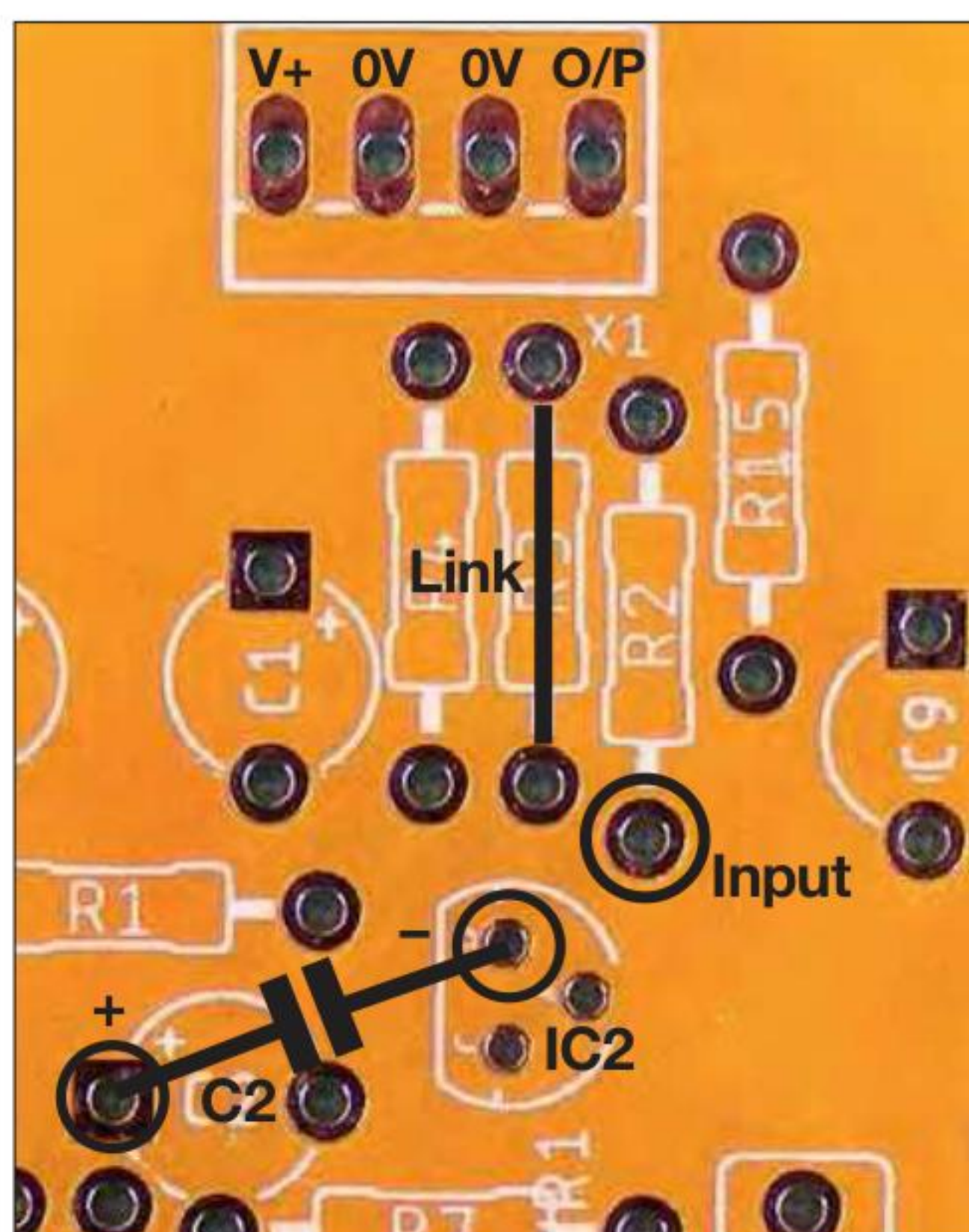


Fig.19. Note how the components are re-jigged on the PCB to omit the noise generator for the Hi-Fi tilt tone control.

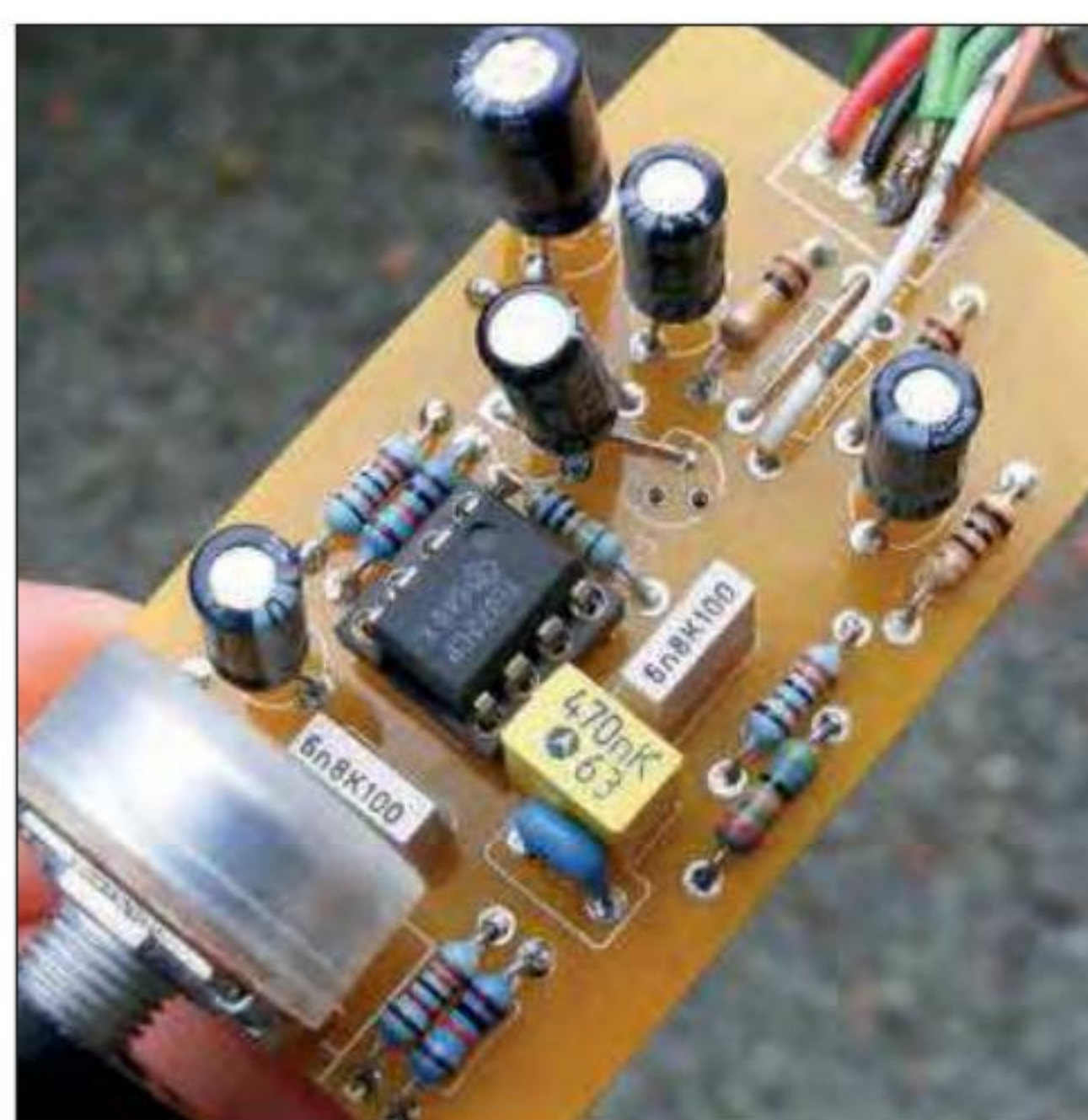


Fig.20. Finished Hi-Fi tone control PCB. Note there are not enough pins on the Molex connector so a spare pad is used for the input connection. This is the black and white striped wire. The input capacitor C2 can be seen jumping to a pad on the voltage regulator outline.

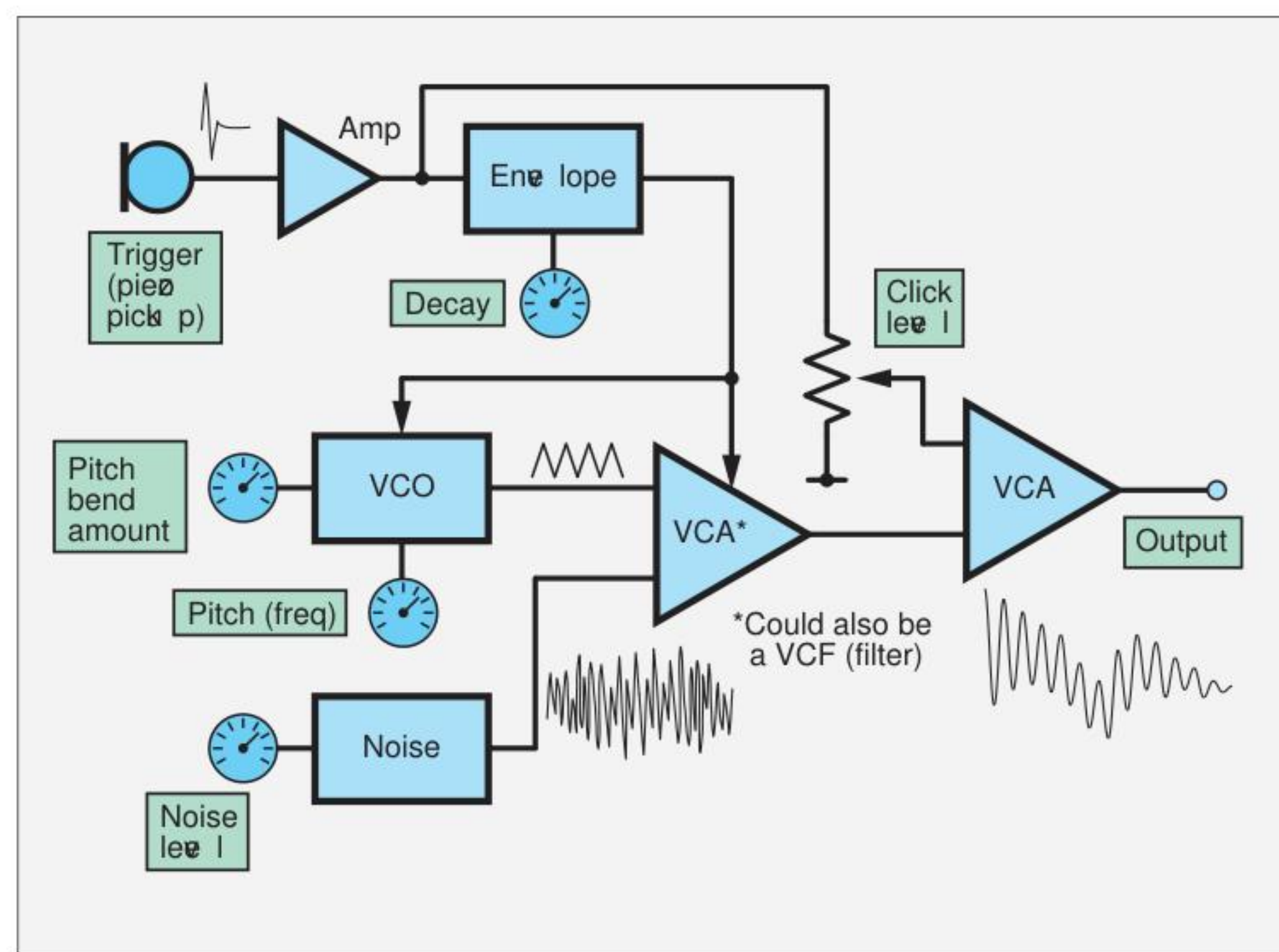


Fig.21. Basic syndrum block diagram.

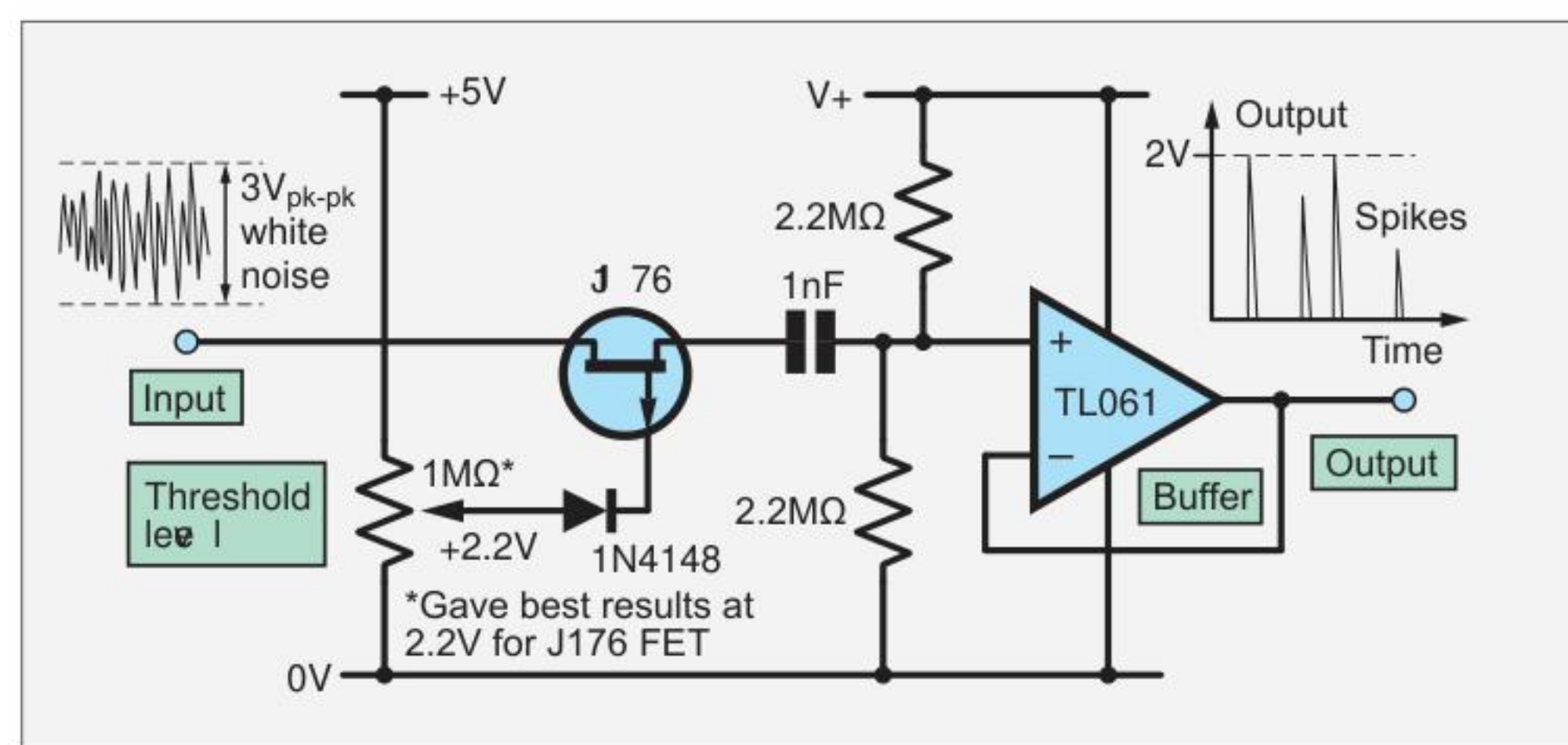


Fig.22. 'Vinyl scratch' generator.

vital part, but there is also anti-phase, low-frequency rumble; wow and flutter; and also distortion effects to add. The JFET circuit shown in Fig.22 produces the short-duration random spikes to produce 'scratches' when fed with random noise. It also makes a good Geiger-counter effect – great for dispersing any eco-warriors who wander into the workshop.

Cymbals and high-hats

These sounds are often generated most simply by putting the white noise through a resonant 10kHz tuned LC circuit filter (Fig.23) often heard in old 1970s electronic organs (Klaus Wunderlich anyone? https://youtu.be/29RU-3q_p9U). A more

metallic effect is achieved by ring-modulating white noise with a high-frequency tone, which generates a whole range of dissonant sidebands. The simplest way of doing this is to use exclusive-or (XOR) gates, which provide the square-wave equivalent of ring modulation. Alternatively, one can just use a hex-inverter chip to generate six square waves together and mix them. This process was used in the Roland TR606 drum machine, a staple of bed-room electronic musicians in the 1980s. Robert Penfold's *Cymbal Synthesiser* in *Electronics Monthly* in December 1984 employed XOR gates.

I created a 'turbine noise' generator, shown in Fig.24 using CD4070 XOR gates and 40106 inverters. Gated and filtered it was also good for cymbals. Varying the supply voltage (3 to 15V) varies the pitch, a useful side effect of the wide operating voltage of old-fashioned CMOS logic.

Visual programming with XOD

By Julian Edgar



Instant pushbutton timer

In this world of ours, timers abound. We've got timers in our smartphones, timers on our kitchen ovens and timers built into our watches. So why would we need a project like this?

Two reasons. First, for 'standard' time periods of the sort you use a lot, this timer can be activated in just moments – far faster than fiddling with a phone or similar. Second, it can be easily wired to either operate a piece of equipment for a pre-set time period, or to sound an alarm when that period has elapsed (or both).

An example use? I am using the timer together with a mains-voltage solid state relay (SSR) to operate my soldering iron. I press the button once and the iron stays on for 15 minutes, press the button twice and it stays on for 30 minutes. Three button presses? – 45 minutes. You get the idea. So rather than glancing up and seeing the iron still switched on a few hours after I last used it (something that used to occur frequently!), the timer gives me a warning beep when it's about to shut down and then turns the iron off, saving power.

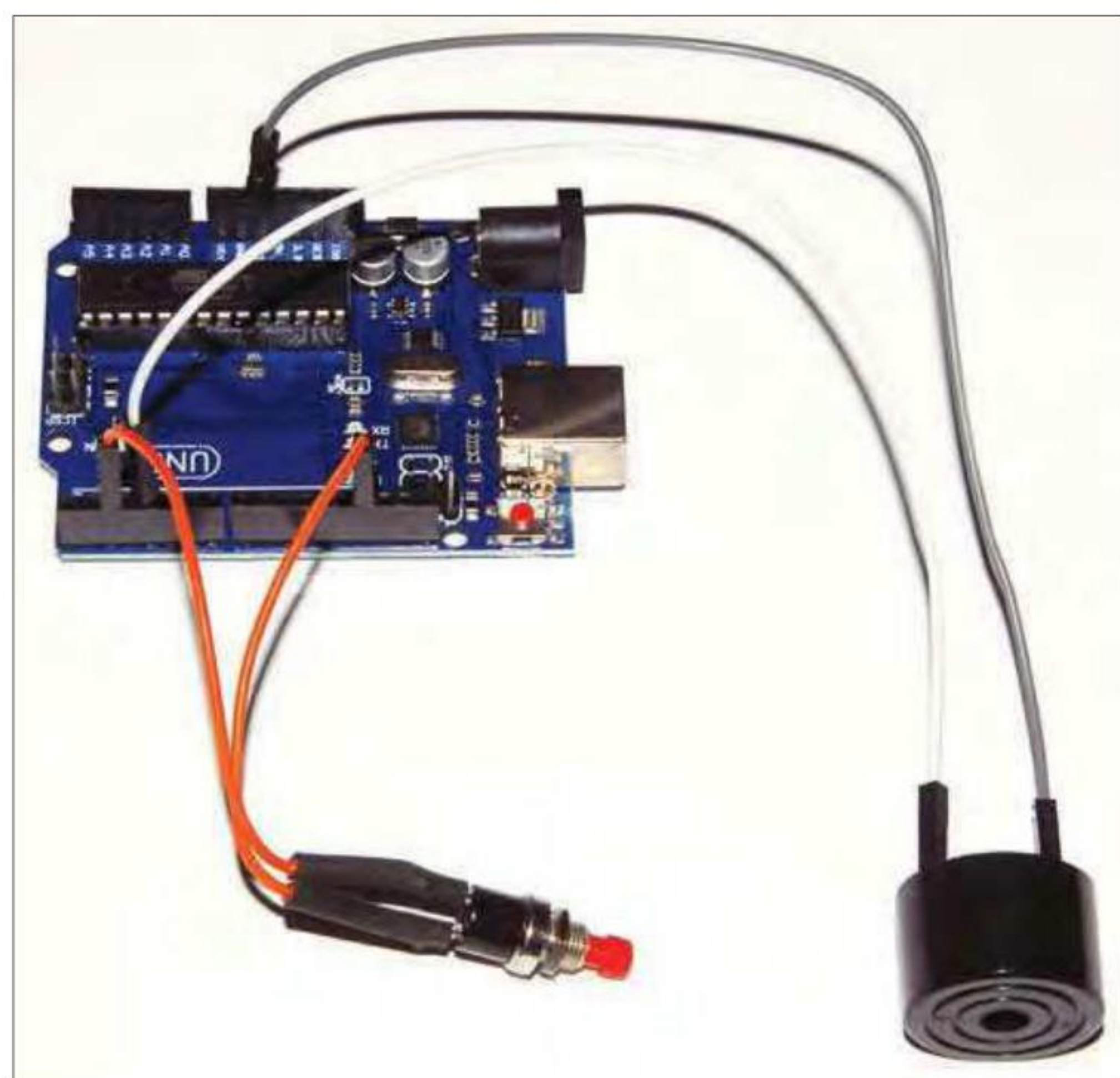


Fig.1. The timer is ultra-fast to operate, user-configurable and uses an Arduino Uno, a pushbutton and a buzzer.

The two key elements of the timer are these. (1) A single pushbutton – that's the only user control. Each time the button is pressed, it adds another time increment to the timed period. (2) The length of the time increment is programmable in the software.

So if you set the time increment to 120 seconds (ie, two minutes), and press the button three times, you have a six-minute timed period. Or, as in the case of the soldering iron, if each increment is 900 seconds (ie, 15 minutes), each button press will add another 15 minutes to the timed period. So rather than being a universal timer configurable for any value, you set it up for the specific use you're making of it.

If you want to cancel the timed period at any stage, just press the button for a longer time. A long press-and-release also cancels the alarm if it is sounding.

Another example use? On older cars, the windscreen washer spray operates only for as long as your finger is on the switch. Add this timer (and a relay or MOSFET module) and you can have the spray operate for 5, 10 or 15 seconds, the time determined simply by how many flicks you make of the lever. (And in that application, you'd leave off the buzzer.) I've been using this type of timer on one of my cars for about eight years and its attraction has never dulled.

Hardware

The timer is based on an Arduino Uno controller. These boards are now available very cheaply indeed. However, note that the cheapest Uno modules do have one 'wrinkle'. Many use a non-standard USB communications chip, which if you are to communicate with it, needs a new PC driver. Some users report that Windows can find the driver by an automatic on-line search, but I had to download the driver from: <http://bit.ly/pe-may20-xod>

If you are new to using Arduinos, perhaps initially stick with 'official' products – these don't need new drivers. The only other parts that are required are a pushbutton momentary switch and a buzzer that can operate on 5V.

Fig.2 shows the connections, and the port numbers (all digital – ie, 'D') are:

- D2** Pushbutton (no pull-up needed)
- D7** Output activated during timed period (eg, feeds a solid-state relay or MOSFET module)
- D4** 5V buzzer
- D13** Optional LED

If you want to add a MOSFET board there are lots available; for example, search on eBay for ‘3-20V MOSFET MOS Transistor Trigger Switch Driver Board PWM Control Module’. At the time of writing, item 303491652040 is just £2.80 delivered. This one is a PWM-controllable MOSFET board, which will work fine and gives you more options for other projects, but this application does not have to have the PWM functionality. Still, at this price, why not?

Software

The pushbutton timer program (‘sketch’) is written in XOD (pronounced ‘Zod’), a free visual programming software that is easy to follow – and very easy to alter. (For an introduction to XOD see the March 2020 issue of *PE*.) After you have installed XOD on your PC (see <https://xod.io/downloads/>), you can download the ‘Push-button timer’ sketch from the May 2020 page of the *PE* website and then upload it to the Arduino.

Refer to Fig.3, which shows the XOD program. Don’t panic! Just like a circuit, it’s easy to break it down into its functional sections.

Starting at the top of the red box, the input of the pushbutton increments a ‘count’ node. Each time the button is pressed, the count node increments by whatever amount has been set by the ‘step’ value. This gives us our timed period. This number is fed to the ‘delay’ node that in turn operates a ‘flip flop’ that turns on the ‘on during period’ node. (The link from ‘count’ to ‘delay’ is actually through an ‘if long hold’ node, that I’ll get to in a moment.)

Refer now to the yellow box. When the timed period ends, another ‘flip flop’ turns on the buzzer for the length of time selected by the ‘length of alarm’ number running a ‘clock’ node. The ‘on-delay’ (even when set for zero) prevents a tiny switch-on squeak from the buzzer.

Up at the top-left (brown box) is a ‘click-hold’ node that determines if the button press is short or long. If it is long (the default is 0.5 seconds) then the time period is set to 0 – ie, it is reset. The sounding of the buzzer is also prevented in this condition – a long button press and release will cancel the buzzer if it is on.

Note how there’s another input from the same pushbutton (green box) – this operates the buzzer on each button press, audibly confirming how many times the button has been pushed.

Finally, the white box shows the nodes used to flash the on-board LED when the ‘count’ is greater than 0; ie, when the timer is active. (This feeds D13, and this port can also be used to flash an external LED if wished.)

The three user-definable constants are:

- Value of the time increment
- Length of time the buzzer sounds at the end of the timed period
- Length of time regarded as a ‘long push’ of the button.

All these values are in seconds. These are easily changed in XOD as required – just click on the ‘VAL’ box and then alter the number in the box in the bottom-left of the screen.

In use

If you wished to use the project as a standalone timer, you could power it from a USB 5V supply and install the Uno, buzzer and pushbutton in a box. If you are installing the device in other equipment, ensure you have a supply of 5-12V available. Switching mains current is most safely done with a solid-state relay; these have the connections clearly marked on them.

Conclusion

Until you use a pushbutton timer like this one, it is honestly hard to describe how useful it is. From boiling an egg to activating a light for a designated time; from timing an exercise session to reminding yourself of a daily activity, I love it. And, with the wonders of modern DIY electronics, it’s never been easier or cheaper to make a timer like this one.

XOD files

The XOD file discussed in this article can be downloaded from the May 2020 page of the *PE* website.

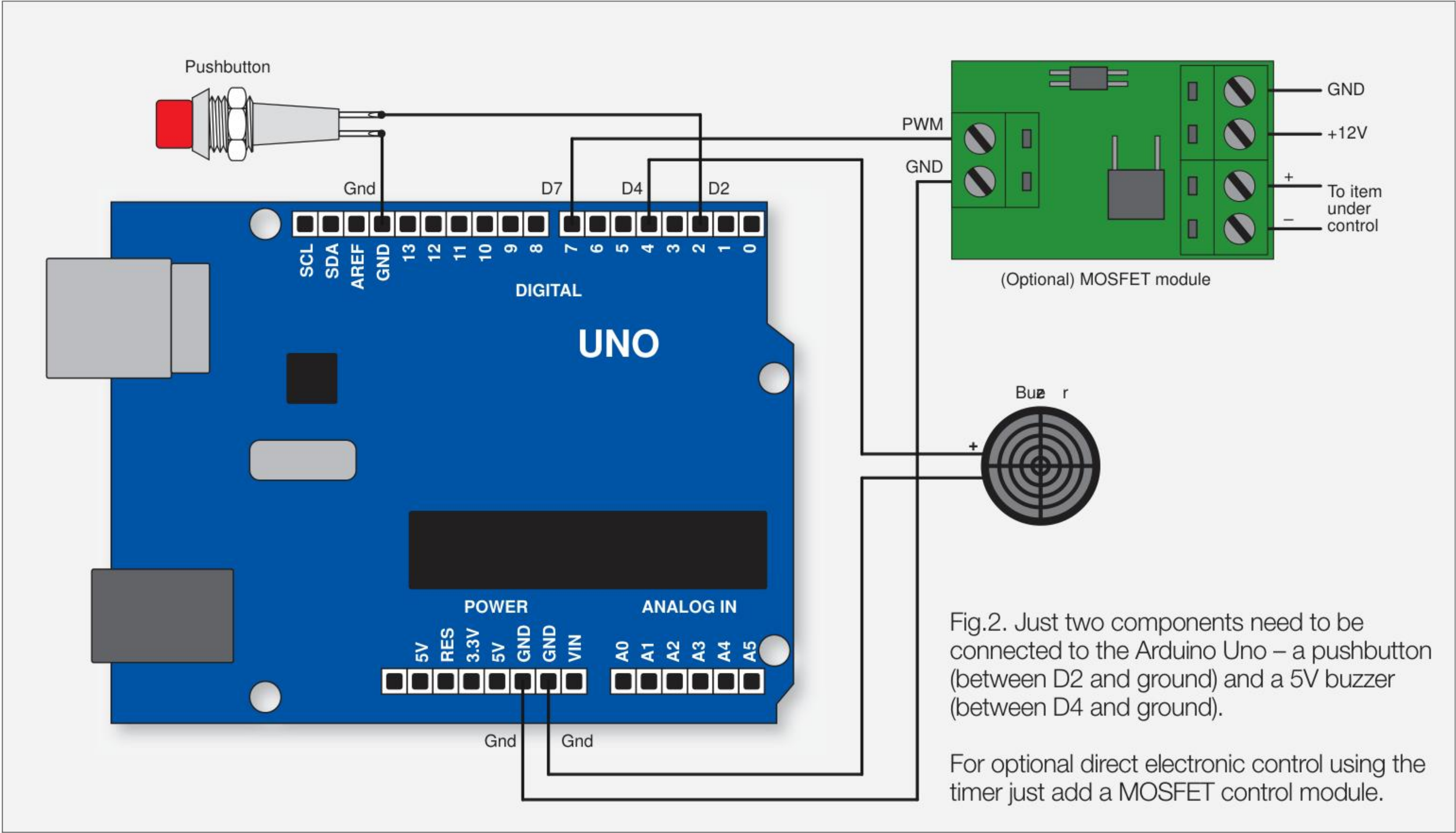


Fig.2. Just two components need to be connected to the Arduino Uno – a pushbutton (between D2 and ground) and a 5V buzzer (between D4 and ground).

For optional direct electronic control using the timer just add a MOSFET control module.

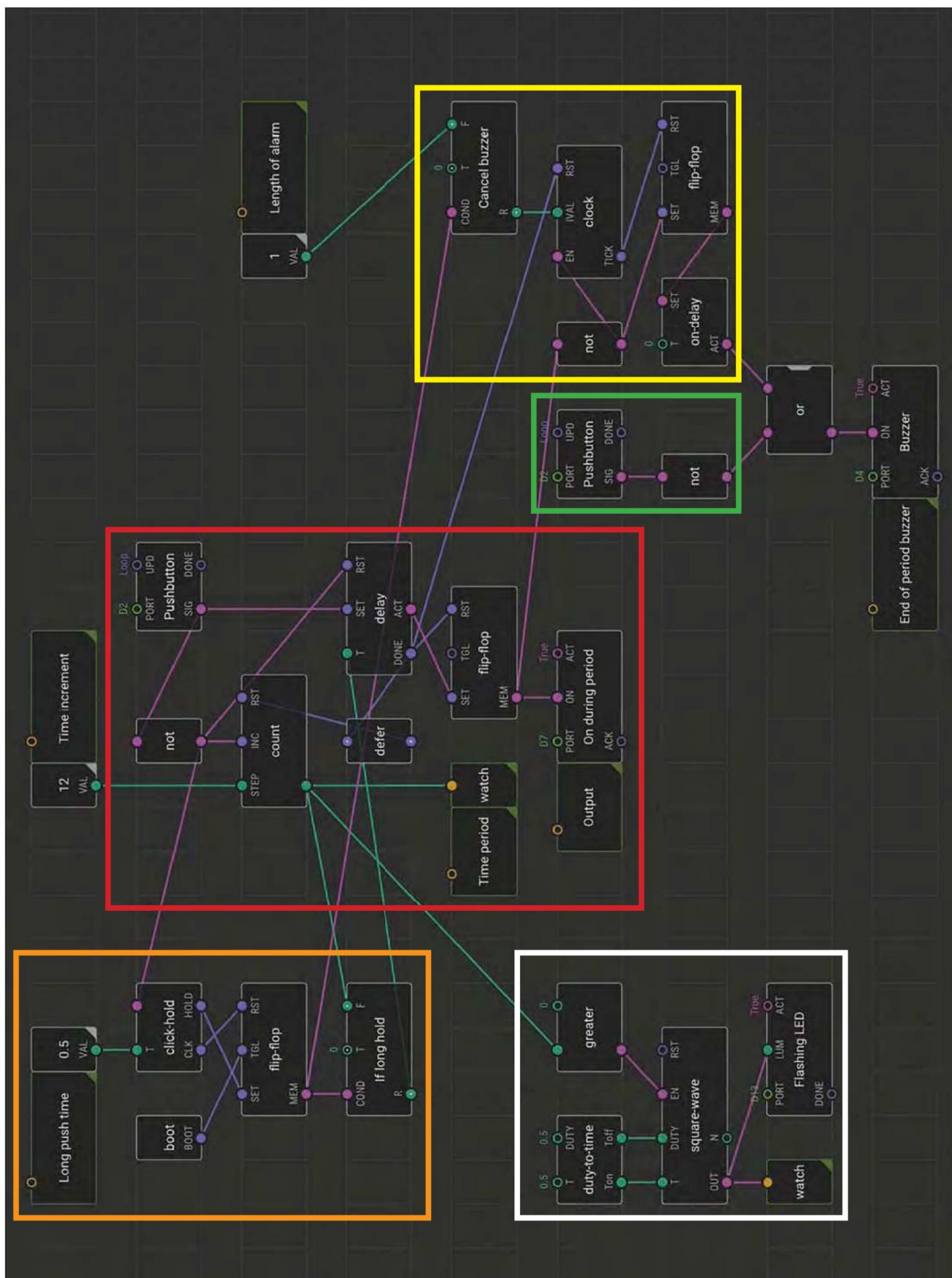


Fig.3. The sketch, written in XOD visual programming language. The timed period is set by pushes of the button (red box), turning on a buzzer when the timed period has elapsed (yellow box). The green box shows how the input of the button is used to trigger the buzzer with each press (giving a confirming beep). The brown

box nodes differentiate between short and long button pushes, and the white box nodes flash an LED during the timed period. Three values may be set by the user – the time increment of each button push, the length of time the alarm sounds, and the length of time regarded as a ‘long’ button push.



Teach-In 8 CD-ROM Exploring the Arduino

This CD-ROM version of the exciting and popular *Teach-In 8* series has been designed for electronics enthusiasts who want to get to grips with the inexpensive, immensely popular Arduino microcontroller, as well as coding enthusiasts who want to explore hardware and interfacing. *Teach-In 8* provides a one-stop source of ideas and practical information.

The Arduino offers a remarkably effective platform for developing a huge variety of projects; from operating a set of Christmas tree lights to remotely controlling a robotic vehicle wirelessly or via the Internet. *Teach-In 8* is based around a series of practical projects with plenty of information for customisation. The projects can be combined together in many different ways in order to build more complex systems that can be used to solve a wide variety of home automation and environmental monitoring problems. The series includes topics such as RF technology, wireless networking and remote web access.



PRICE
£8.99

Includes P&P to UK if
ordered direct from us

PLUS: PICs and the PICkit 3 – A beginners guide

The CD-ROM also includes a bonus – an extra 12-part series based around the popular PIC microcontroller, explaining how to build PIC-based systems.

SOFTWARE

The CD-ROM contains the software for both the *Teach-In 8* and PICkit 3 series.

ORDER YOUR COPY TODAY!

JUST CALL 01202 880299 OR VISIT www.electronpublishing.com

PE Practical
Electronics

BACK ISSUES

EPE EVERYDAY PRACTICAL
ELECTRONICS

FEBRUARY 2020

PROJECTS • Audio DSP – Part 2 • Motion-Triggered 12V Switch • USB Keyboard and Mouse Adaptor for Micros • Using Cheap Asian Electronic Modules – Part 21 • Colour Maximite Computer – Part 4

FEATURES • The Fox Report • Techno Talk • Net Work • Practically Speaking • Using Stepper Motors • Circuit Surgery • Audio Out • Make it with Micromite • Max's Cool Beans • Electronic Building Blocks



MARCH 2020

PROJECTS • Diode Curve Plotter • Audio DSP – Part 3 • Steam Train Whistle / Diesel Horn Sound Generator • Using Cheap Asian Electronic Modules – Part 22

FEATURES • The Fox Report • Techno Talk • Net Work • PIC n' Mix • Circuit Surgery • Audio Out • Make it with Micromite • Visual programming with XOD • Max's Cool Beans • Electronic Building Blocks



APRIL 2020

PROJECTS • Ultra-low-distortion Preamplifier with Tone Controls – Part 1 • iCEstick – Part 1 • Flip-dot Display

FEATURES • Techno Talk • Net Work • Practically Speaking • Circuit Surgery • Audio Out • Make it with Micromite • Max's Cool Beans • Visual programming with XOD



BACK ISSUES – ONLY £5.80

£5.80 per issue for UK incl p&p ■ £6.75 Europe Air Mail ■ £7.50 ROW Air Mail

We can supply back issues of PE/EPE by post.

We stock magazines back to 2006, except for the following:

2006 Jan, Feb, Mar, Apr, May, Jul
2007 Jun, Jul, Aug
2008 Aug, Nov, Dec
2009 Jan, Mar, Apr
2010 May, Jun, Jul, Aug, Oct, Nov
2011 Jan
2014 Jan
2018 Jan, Nov, Dec
2019 Jan, Feb, Apr, May, Jun

Issues from Jan 1999 are available on CD-ROM / DVD-ROM

If we do not have a paper version of a particular issue, then a PDF can be supplied for the same price. Your email address must be included on your order.

Please make sure all components are still available before commencing any project from a back-dated issue.

ORDER FORM – BACK ISSUES

☐ Back issues required (month / year)

Name

Address

..... Tel:

Email

☐ I enclose cheque/PO to the value of £

☐ Please charge my Visa/Mastercard £



Card No

Valid From Card Expiry Date

Card Security Code (Last three digits on or under the signature strip)

SEND TO: **Practical Electronics, Electron Publishing Limited**
113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU

Tel: 01202 880299

Email: stewart.kearn@wimborne.co.uk

On-line Shop: www.electronpublishing.com

Payments must be in £ sterling – cheque must be drawn on a UK bank and made payable to 'Practical Electronics'. All items normally posted within seven days of receipt of order. Copy this form if you do not wish to cut your issue.



Flashing LEDs and drooling engineers – Part 3

The problem with things like switches and LEDs is that there's always something more to wrap your brain around. In the first column in this miniseries (*PE* March 2020), for example, we started by looking at a single-pole, single-throw (SPST) switch directly driving a single unicolour LED (Fig.1a). In this case, the results were fairly rudimentary: Switch is On (Closed), LED is On; Switch is Off (Open), LED is Off. One possibility that we didn't consider would have been to use a single-pole, double-throw (SPDT) switch to directly drive two unicolour LEDs (Fig.1b).

Our next step was to use our SPST switch to drive the input of a microcontroller unit (MCU), and to use one of the MCU's outputs to drive our solitary unicolour LED (Fig.2a). Later, in our second column (*PE* April 2020), we used our MCU to take the signal from the SPST switch and use it to drive a pair of unicolour LEDs (Fig.2b).

The great thing about using an MCU is that we don't need an SPDT switch, along with two input pins on our microcontroller, to drive our two LEDs. The MCU can use a single pin to determine the state of an SPST switch and use this information to control the LEDs. (It probably goes without saying – but I'll say it anyway – that we can always use an SPDT switch in the role of an SPST switch by simply ignoring one of its normally closed (NC) or normally open (NO) contacts.)

EEK! Three states!

As I mentioned in my column on electrical switch terminology (<https://bit.ly/30ZpToT>), it's also possible to obtain single-pole, centre-off (SPCO) switches, which are also known as single-pole, changeover switches. These are toggle or rocker switches that look like SPDT switches – including their schematic symbols – except that they have three positions for the actuator (lever or rocker). If we think of an SPST switch as acting in an On-Off manner, then we might consider an SPDT

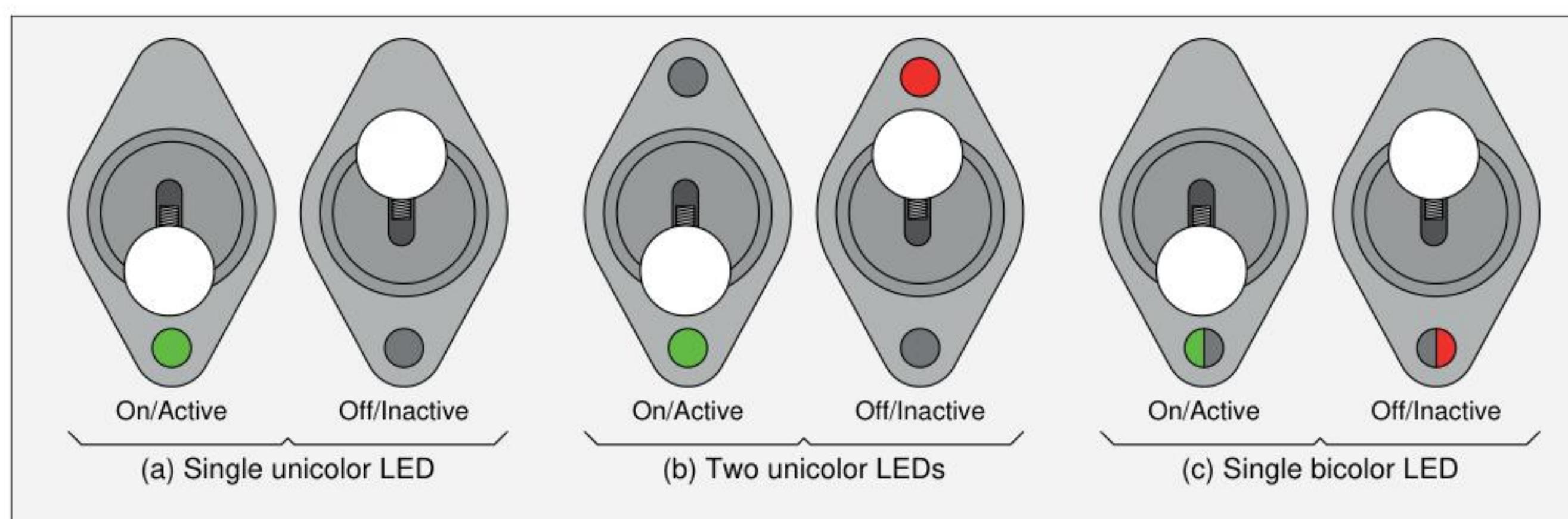


Fig.2. SPST switch driving one unicolour LED, two unicolour LEDs, and one bicolour LED.

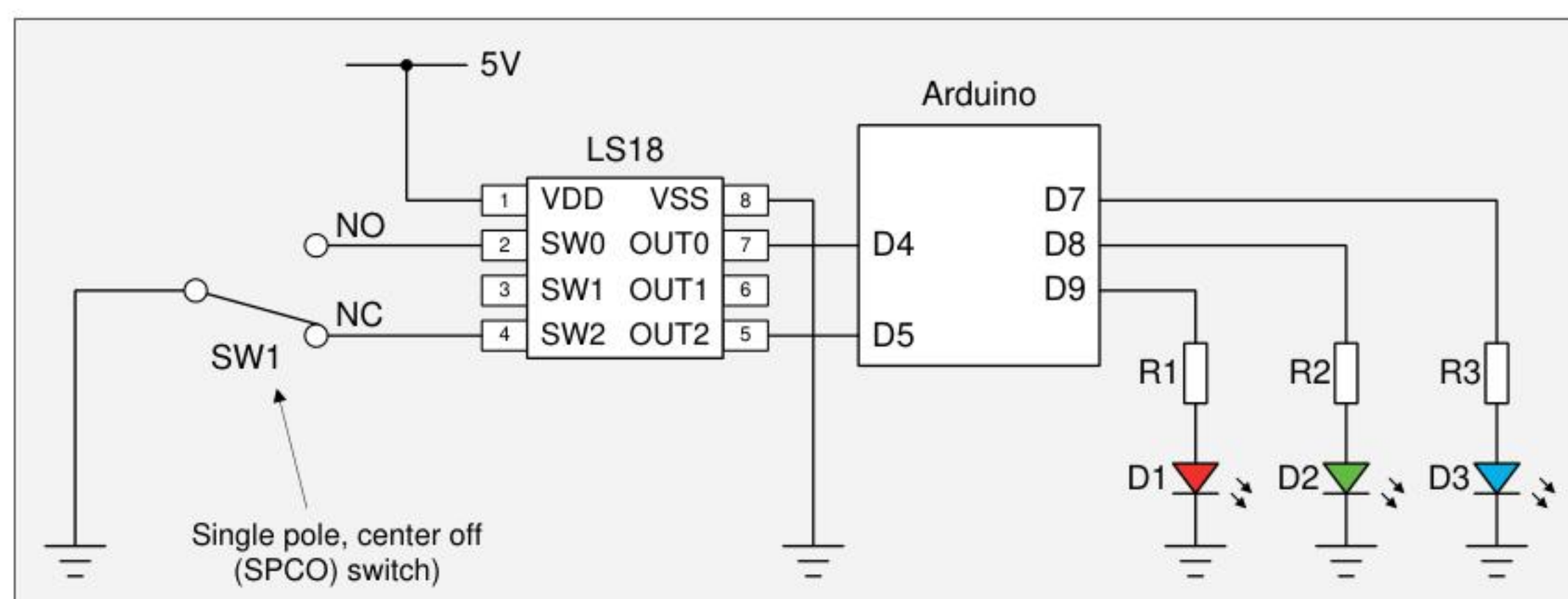


Fig.3. Using an SPCO switch and MCU to drive three LEDs.

switch as performing an On-On operation, while an SPCO switch behaves in an On-Off-On fashion.

Purely for the sake of discussion, let's assume that we have the NC and NO contacts of an SPCO switch connected to two inputs of an MCU, and that we are using the MCU to control three LEDs (Fig.3). Observe that, in this particular example, we don't need to use pull-up resistors on the switch's NC and NO contacts because these are provided in the LS18 IC that we are using for debouncing (we discussed this IC, which comes from **LogiSwitch.net**, in *PE* March 2020).

The idea is, if the switch is toggled one way, the NC terminal (and hence pin D5 on the MCU) will be connected to 0V while the NO terminal (and hence pin D4 on the MCU) will be pulled up to 5V. By comparison, if the switch is toggled the other way, the NO terminal will be connected to 0V while the NC terminal will be pulled up to 5V. Finally, if the switch is in its centre position, both the NC and NO terminals will be pulled up to 5V. Our MCU program can use this information to determine which of the three states the switch is in and to light one of the three LEDs accordingly.

But what if we have only a single unicolour LED, as illustrated in Fig.2a, but we are using an SPCO switch? If we refer to the three states of our switch as being 'Up', 'Centre' and 'Down', then one possibility would be as follows (where 'long' could be 800ms, 'short' could be 200ms, and 'cycles' means we repeat the actions over and over again):

Switch -> Up: LED cycles On short and Off long
 Switch -> Centre: LED is Off
 Switch -> Down: LED cycles On long and Off short

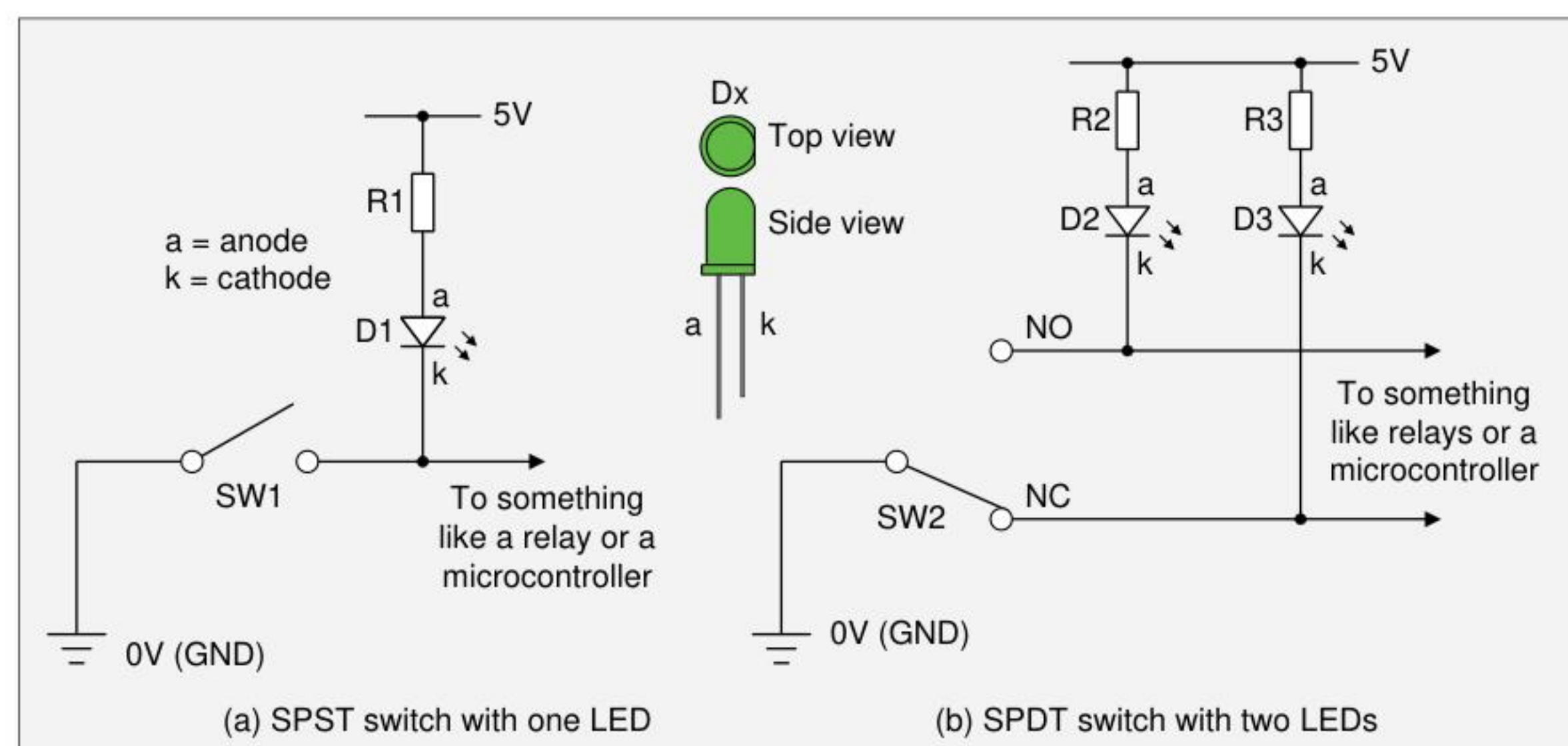


Fig.1. SPST and SPDT switches driving LEDs directly.

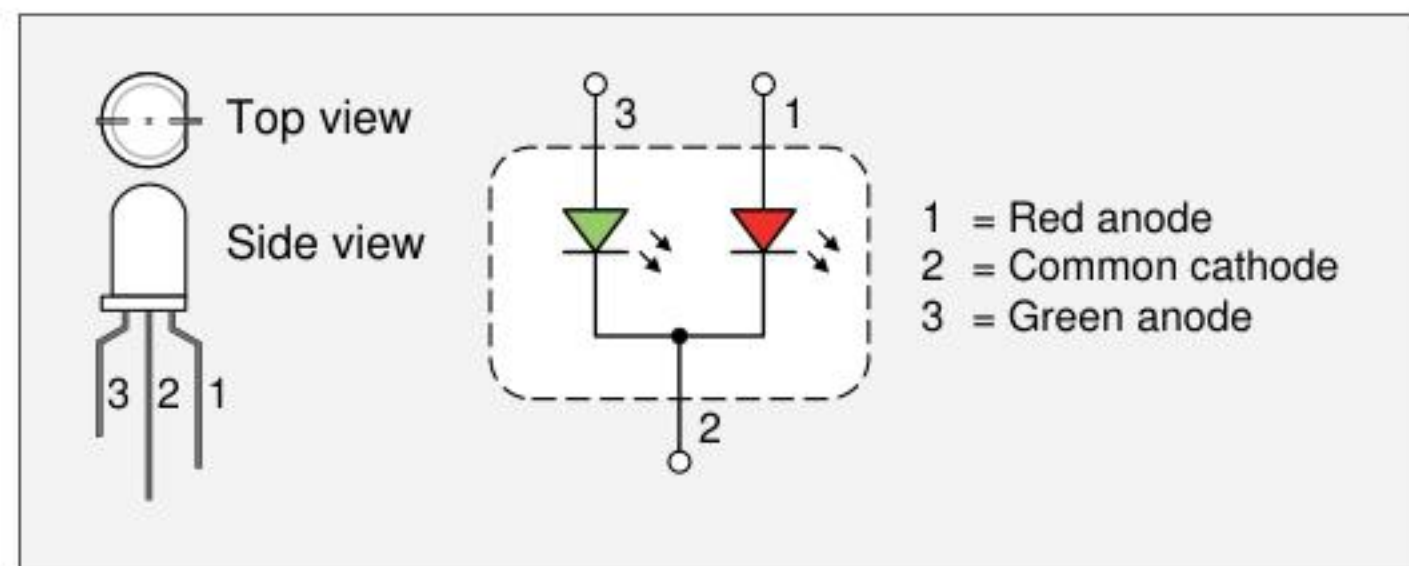


Fig.4. Bicolour LED with three terminals (common cathode).

Another possibility for the Centre position would be to have the LED ‘breathing’ (ie, repeatedly fading up and fading down).

How about if we have two unicolour LEDs called GLED (green) and RLED (red), as illustrated in Fig.2b, but – once again – being used in conjunction with an SPCO switch? In this case, we could implement something like the following:

Switch -> Up: GLED -> Off; RLED -> On
 Switch -> Centre: GLED -> Off; RLED -> Off
 Switch -> Down: GLED -> On; RLED -> Off

Once again, another possibility for the Centre position would be to have both of the LEDs breathing, or maybe have them both present a periodic flash (say turning On for 100ms once every second).

We want more!

Now sit down, take a deep breath, and try to curb your natural enthusiasm because we’re about to dip our toes into the bicolour waters (remember to take your socks off first). There are a variety of different types of bicolour LEDs around. The first component we will be playing with, which contains red and green LEDs, is part number 160-1939-ND from [Digikey.com](https://bit.ly/2uPq8Hh) (<https://bit.ly/2uPq8Hh>). This little rascal sports three pins: a red anode, a green anode, and a common cathode (Fig.4). Other colour combinations are available, as are common anode configurations with one anode and two cathodes.

Looking at the data sheet for this little scamp (<https://bit.ly/2TvpEhW>), we see that the forward current (I_f) is 30mA for both diodes. Meanwhile, the forward voltage drop (V_f) is 2.0V for the red diode and 2.1V for the green diode. Let’s assume they are both 2.0V, which is ‘close enough for government work,’ as they say.

At this point we have a choice. If both of the forward-voltage drops are the same, and both of the forward currents are the same, and if we only ever intend to have one diode on at a time, then we can get by with a single current-limiting resistor, as illustrated in Fig.5a. Using Ohm’s law ($V = IR$), and remembering we’re assuming a power supply of 5V, a forward voltage drop of 2V, and a forward current of 30mA (0.03A), then $R_{gr} = (5 - 2)/0.03 = 100\Omega$.

Having said this, do you seriously expect me to not try turning both LEDs on at the same time to see what the resulting yellow colour looks like? If so, you have seriously

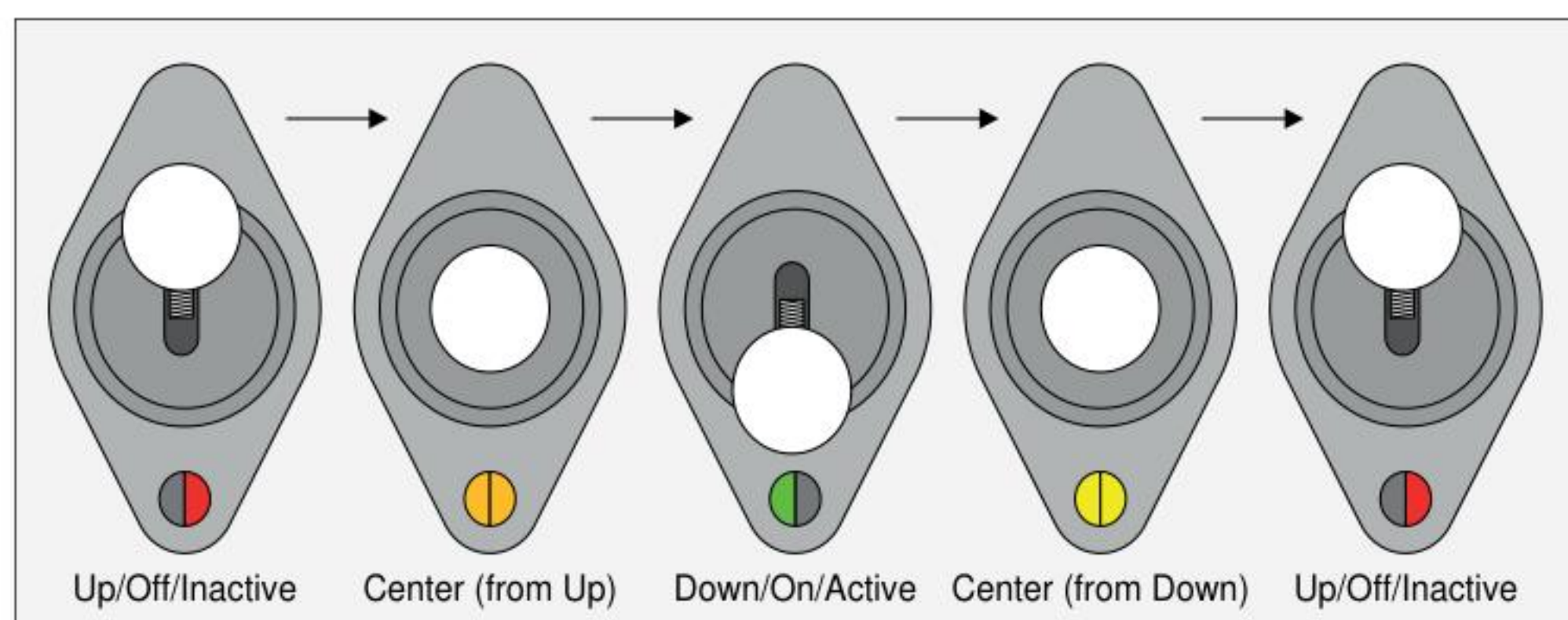


Fig.6. Using a bicolour LED with an SPCO switch and with two colours for the centre position.

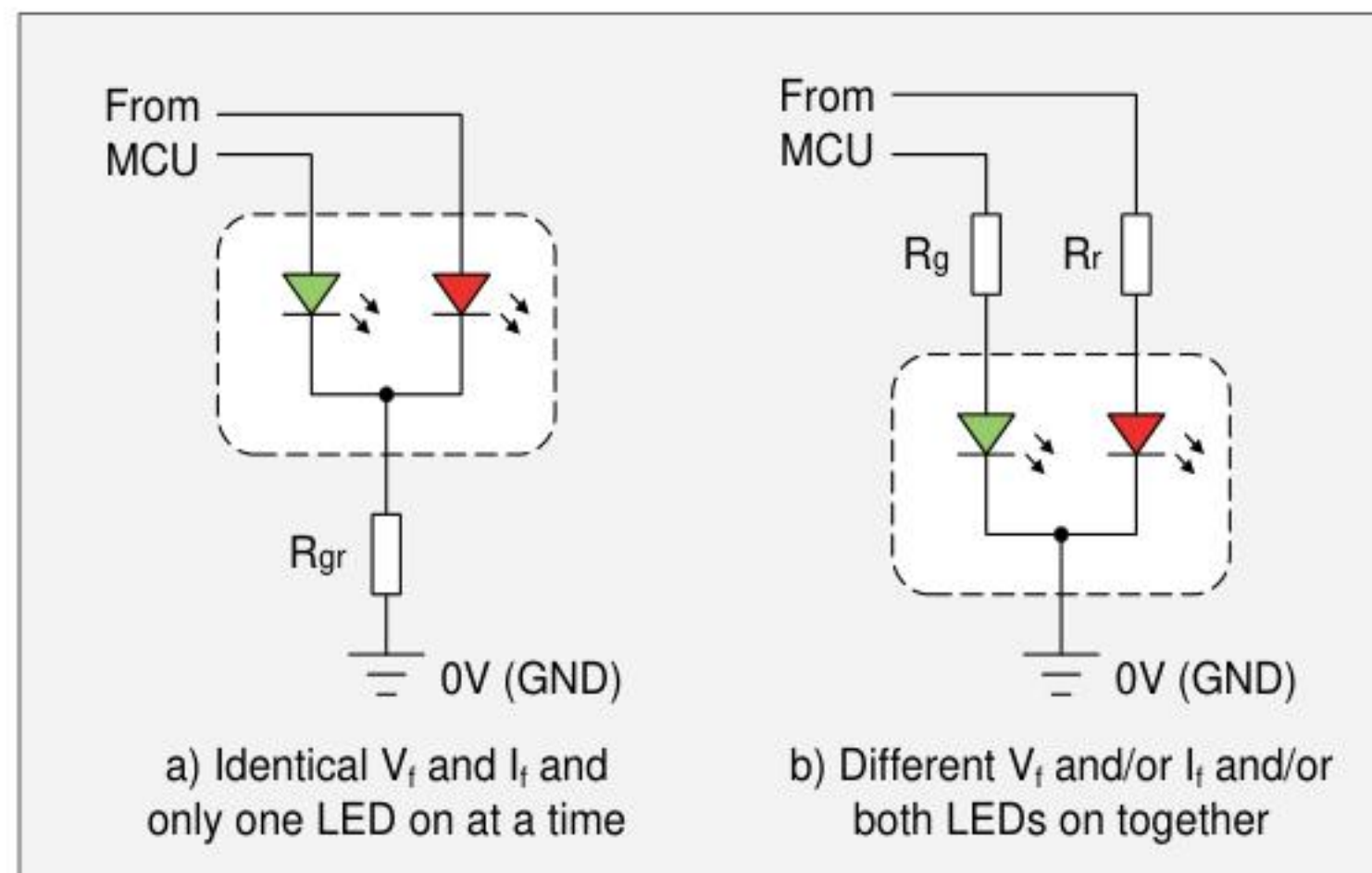


Fig.5. Alternative bicolour LED current-limiting resistor configurations.

underestimated your man. But this means we have to modify our circuit. Even though both of the forward-voltage drops and forward currents are the same, the fact that we intend to occasionally have both LEDs illuminated at the same time means that each LED will require its own current-limiting resistor, as illustrated in Fig.5b. In this particular example, both of the resistors will have the same value, but we would have to determine the values individually if the forward voltage drops and/or the forward current values were different for the LEDs.

Just for giggles and grins (and because I just rooted one out of my treasure chest of salvaged parts) let’s assume we have an SPCO switch and MCU controlling a single bicolour LED. One possibility would be as follows:

Switch -> Up: GLED -> Off; RLED -> On (red)
 Switch -> Centre: GLED -> On; RLED -> On (yellow)
 Switch -> Down: GLED -> On; RLED -> Off (green)

Actually, by varying the relative intensity of the red and green LEDs we should be able to achieve at least four colours: red, green, yellow, and orange. To be honest, using the pulse-width modulation (PWM) technique we discussed in an earlier column, I would have assumed that values of red = 255 and green = 255 would have resulted in yellow, while red = 255 and green = 128 would have resulted in orange. In reality, however, I had to mess around with the values a bit to get anything approaching the orange and yellow I was looking for.

The point is, if we do have four colours, then we can make things even more spiffy as follows (Fig.6):

Switch -> Up: LEDs -> Red
 Switch -> Down: LEDs -> Green
 Switch was Up (red) -> Centre: LEDs -> Orange
 Switch was Down (green) -> Centre: LEDs -> Yellow

If you wish, you can download a sketch (**CB-LED-Pt3-May20.txt**) for this scenario to see how I implemented it from the May 2020 page of the *PE* website. Furthermore, I’ve created a short video to show all of this in action (<https://bit.ly/2vV7oXk>).

If we wanted to make things even more spiffy (and why wouldn’t we?), we could implement a breathing effect for the yellow and orange centre positions.

Now, suppose we had something like Fig.2b but with two bicolour LEDs? How about you reflect on some of the lighting effect possibilities you could use with SPST, SPDT, and SPCO switches, and then email me to tell me what you’ve come up with?

What? More?

There is another type of bicolour LED that has only two pins. For the purpose of these discussions, the component we will be playing with is part number 160-2245-ND from Digikey.com

(<https://bit.ly/38nFTmo>). This little scamp contains a yellow LED and a green LED (Fig.7), but other colour combinations are available.

Looking at the data sheet for this little chap (<https://bit.ly/3cyH7i3>), we see that we’re going to have a bit of a problem.

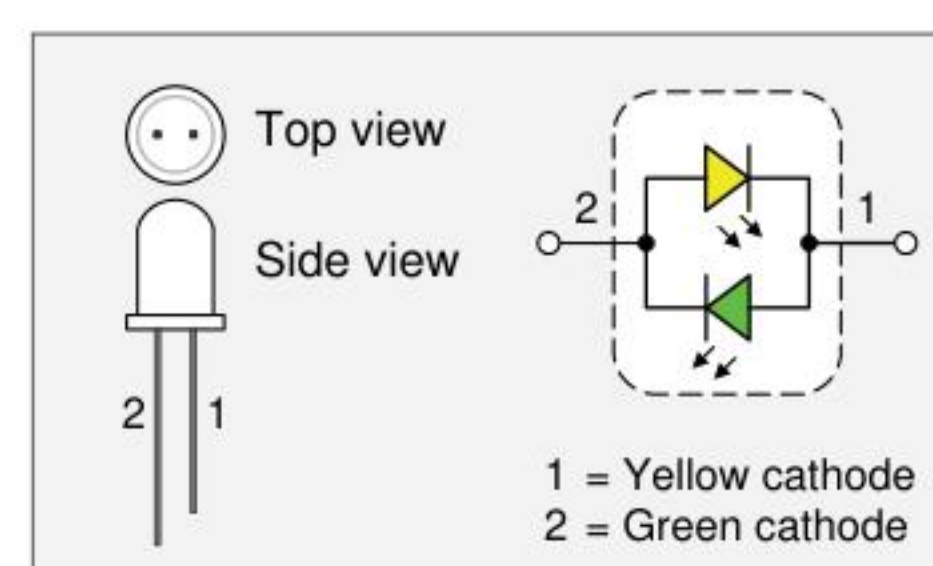


Fig.7. Bicolour LED with two terminals.

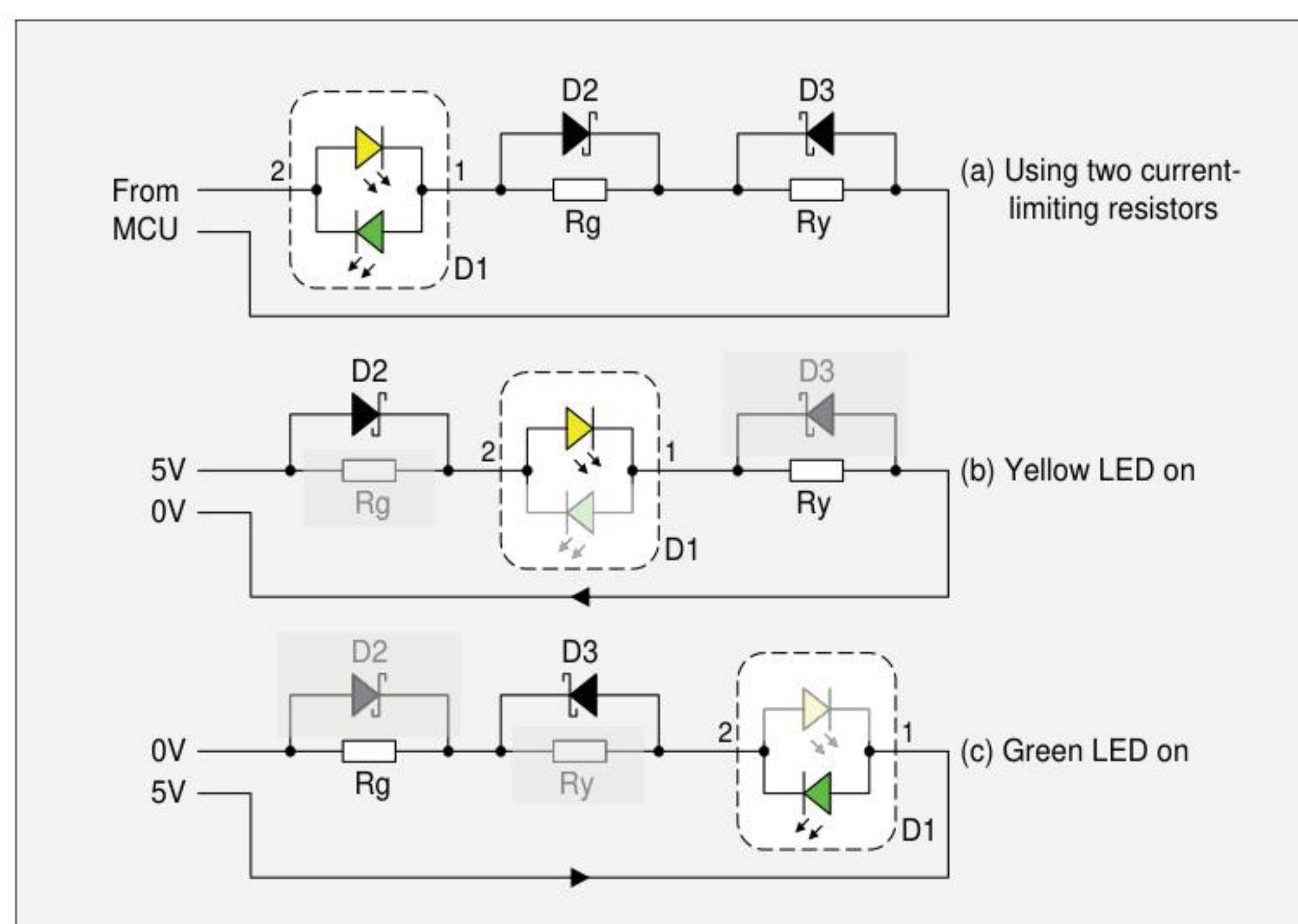


Fig.8. Using two 1N5817 Schottky diodes in parallel with two current-limiting resistors.

On the bright side, the forward voltage drop (V_f) is 2.1V for both LEDs. On the downside, the forward current (I_f) is 20mA for the yellow LED and 30mA for the green LED.

Isn't it ironic? When we were working with the three-terminal bicolour LED, the forward voltage and current values were the same for both LEDs, which means we could have gotten by with a single resistor so long as we didn't illuminate both LEDs at the same time. In the case of our two terminal bicolour LED, we can only ever have one of the LEDs on at any one time, but – since the forward currents are different – we need a different current-limiting resistor for each LED. The problem is that we can have only one current-limiting resistor (it doesn't matter to which side of the bicolour device the resistor is connected), or can we?

This is where we roll up our sleeves and reveal just how cunning we can be (shut the doors and close the curtains because we don't want the unwashed masses to learn all our secrets). What we're going to do is use two current-limiting resistors, each in parallel with a 1N5817 Schottky diode, as illustrated in Fig.8a.

In reality, we could use any general-purpose diode, like a 1N4001. The main reason for using these Schottky diodes is their low forward-voltage drop, which will be 0.32V according to the data sheet (<https://bit.ly/32QgRLA>).

Now, this can take a little time to wrap your brain around, but we'll take it step by step. Remember, we're using an Arduino Uno as our MCU, which mean its digital outputs switch between 0V and 5V. What we are going to do is to use two of our digital outputs to control our bicolour LED.

If we set the MCU output connected to pin 2 of the bicolour LED to HIGH (5V) and the other MCU output to LOW (0V), then the yellow LED will be forward biased and will turn on, while the green LED will be reversed biased and will turn off (Fig.8b). Also, Schottky diode D2 will be forward biased, which means it will turn on, thereby shorting out resistor R_g , which means the circuit acts like R_g doesn't exist. Meanwhile, Schottky diode D3 will be reverse biased, which means it will be turned off, which means the circuit acts like D3 doesn't exist.

Remembering that the V_f of the yellow diode is 2.1V, the V_f of Schottky diode D2 is 0.32V, and the I_f of the yellow diode is 20mA (0.02A), then using $V = IR$, $R_y = (5 - 2.1 - 0.32)/0.02 = 129\Omega$. Since the closest E24 series resistor is 130 Ω , we're right on the nose.

By comparison, if we set the MCU output connected to pin 2 of the bicolour LED to LOW (0V) and the other MCU output to HIGH (5V), then the green LED will be forward-biased and will turn on, while the yellow LED will be reversed-biased

and will turn off (Fig.8c). Also, Schottky diode D3 will be forward-biased, which means it will turn on, thereby shorting out resistor R_y , which means the circuit acts like R_y doesn't exist. Meanwhile, Schottky diode D2 will be reverse-biased, which means it will be turned off, which means the circuit acts like D2 doesn't exist.

Remembering that the V_f of the green diode is 2.1V, the V_f of Schottky diode D3 is 0.32V, and the I_f of the green diode is 30mA (0.03A), then using $V = IR$, $R_g = (5 - 2.1 - 0.32)/0.03 = 86\Omega$. In this case, the closest E24 series resistor is 82 Ω , which – once again – is 'close enough for government work.'

What's that you say? 'Why do the three circuit incarnations in Fig.8 differ from each other?' Actually, I'm just messing with your head. Since this is a series circuit (if we regard each Schottky-resistor combo to be a series element), then as far as the forward/reverse biasing of the Schottky diodes or the turning On and Off of the yellow and green LEDs, all of these circuits are functionally equivalent. The only reason I drew them in different ways here was to emphasise that fact.

What happens if we switch back and forth between the two colours really quickly? If this was a red-green bicolour diode, I'd expect to see yellow. Since all I have is a yellow-green bicolour diode, I have no idea, but I'm looking forward to finding out when I get a spare minute, after which I'll create a video and make the code available for you to download in my next column.

Next time

In my next column, we will start to consider tricolour LEDs, which are beasts of a different colour (pun intended). In the meantime, I welcome your comments, questions, and suggestions.

Extra! – Awesome clock using 7-segment displays

Since we are currently submerging ourselves in all things LED-related, I thought I'd share a rather awesome clock project I ran across recently on [Hackaday.io](https://bit.ly/39ra4uC) (<https://bit.ly/39ra4uC>). This bodacious beauty, which was created by a Hackaday member who goes by the username of *Frugha*, is based on the humble 7-segment LED display.

Frugha used 6 rows $\times$ 12 columns = 144 of these little rascals to create a display matrix. Frugha also used an Arduino Nano, a real-time clock (RTC), and 18 MAX7219 7-segment display driver ICs to implement a device that is awesome in every way I can think of (Fig.9).

There are so many subtleties about this, such as the way Frugha uses individual segments to 'smooth' the edges of his characters. Also, the way in which adjacent digits 'share' a column, with the upper-right corner of one digit sharing the column with the lower-left corner of the digit to its right. All I can say is I love this little scamp (the clock, not Frugha, although I'm sure he or she is a very lovable person).



Fig.9. Awesome clock made out of 7-segment displays.



Cool bean Max Maxfield (Hawaiian shirt, on the right) is emperor of all he surveys at CliveMaxfield.com – the go-to site for the latest and greatest in technological geekdom.

Comments or questions? Email Max at: max@CliveMaxfield.com



Since I'm providing downloadable Arduino sketches (programs) to accompany the current miniseries of *Cool Beans* columns, I thought it might be a good idea to provide a rationale for the coding style I use. In my first coding column (*PE* March 2020) we talked about cases, spaces, comments, `#define` statements, and why using 'magic numbers' is a bad idea. In my second column (*PE* April 2020) we considered naming conventions for our variables and functions, the use of curly brackets `{ }`, and using four-space indentation. Now, let's take a slightly deeper dive into some of the more nitty-gritty details.

I can see you!

For the purpose of these discussions, we will consider a program that is contained in a single file. The term 'scope' refers to the accessibility (visibility) of variables in a program.

A global variable (a variable that is declared *outside* of any function) is said to have a global scope because it's visible to any and all of the functions in the program. Consider the following two declarations and initialisations of global variables:

```
int      StartCountA = 0;
const int StartCountB = 0;
```

Both of these variables can be read by any of the functions in the program, but only `StartCountA` can be overwritten with a new value. The use of the `const` ('constant') keyword with the declaration of `StartCountB` means that its value cannot be changed after its original initialisation.

By comparison, a local variable (a variable that is declared *inside* a function) has scope only within that function and is not visible to any of the other functions in the program. This means that it's possible to declare local variables with identical names in multiple functions, but each of these variables will be seen only by the functions in which they are declared.

Remember that we are using upper and lower camel case for our global and local variables, respectively.

Newbie programmers often make all of their variables global, which isn't a problem in small programs, but it's not a good habit to adopt because it makes larger programs difficult to understand and maintain.

Foxy `for ()` loops

When using a `for ()` loop, many programmers declare the controlling variable as a local variable. It's also common to use the letters `i` and `j` to name these variables, where `i` typically stands for 'index' and `j` is just the next letter after `i`; for example:

```
int i, j; // Declare local variables

for (i = 0; i < MAX_ROW; i++)
{
    for (j = 0; j < MAX_COL; j++)
    {
        // Do something useful
    }
}
```

There are several things I would do differently here. First, I wouldn't declare `i` and `j` as local variables to the function, but I would instead declare them as part of the `for ()` statements as shown below:

```
for (int i = 0; i < MAX_ROW; i++)
{
    for (int j = 0; j < MAX_COL; j++)
    {
        // Do something useful
    }
}
```

Next, over the years I've come to realise that having single-letter variables can cause more trouble than they are worth, not the least that they don't actually give any indication as to what they do. I now believe that three letters is a rule-of-thumb minimum. Also, on the basis that – in this example – we are using both of our variables to index across rows and columns, I would write this snippet of code as follows:

```
for (int iRow = 0; iRow < MAX_ROW; iRow++)
{
    for (int iCol = 0; iCol < MAX_COL; iCol++)
    {
        // Do something useful
    }
}
```

When we subsequently use the `iRow` and `iCol` variables in the body of our nested `for ()` loops to implement some form of algorithm, having meaningful names makes it much easier to understand and maintain the code.

More regarding `for ()`

There's actually something rather clever about `for ()` statements that professional programmers don't even think to mention, which may explain why non-professional programmers don't know anything about it. Consider the following:

```
for (initialization; condition; modification)
{
}
```

As we see, there are three semicolon-separated parts to this statement: initialisation (where we initialise our control variable); condition (where we test our control variable); and modification (where we increment or decrement) our control variable. Because we typically employ increments and decrements of one, using things like `iRow++` and `iRow--` respectively, beginners often think that's all we can do. But if we remember that `iRow++` is the same as saying `iRow = iRow + 1`, we quickly realise that our modification could be by any positive or negative integer amount such as `iRow = iRow + 3`.

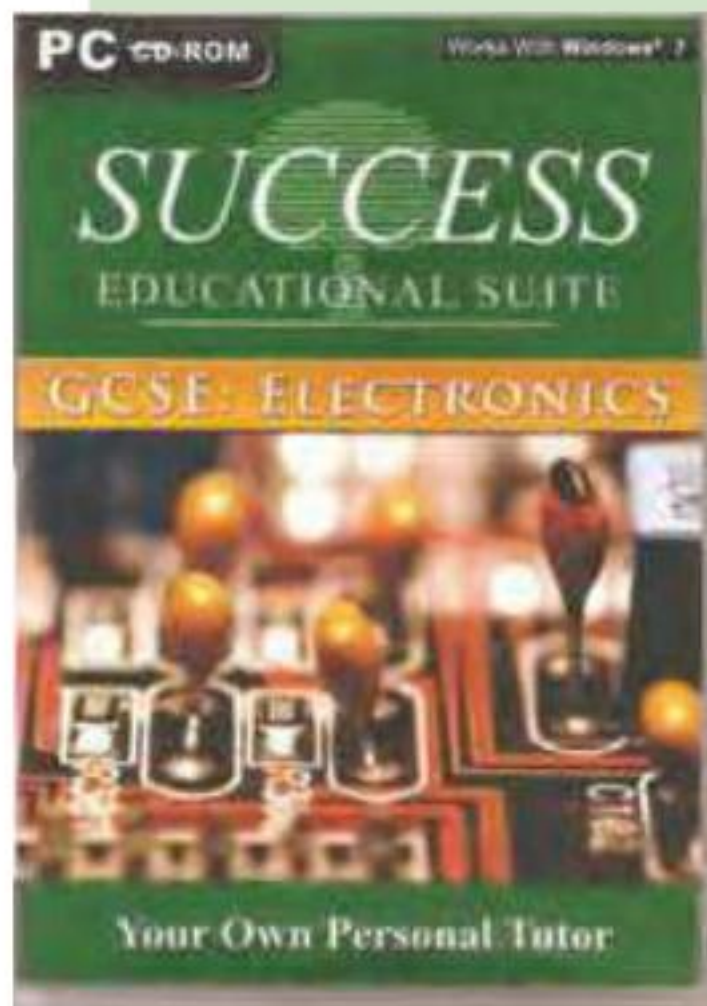
But wait, there's more, because both the initialisation and modification sections can comprise multiple comma-separated elements; for example:

```
for (i = 0, j = 10; i < 10; i++, j--)
{
}
```

I know, I know... this example breaks all my rules (single-character variables and magic numbers), but we're only doing this to illustrate a point, so I'm going to let myself off with a warning.

In my next column, among other things, we'll talk about the way in which the `<<` and `>>` operators work.

PRACTICAL ELECTRONICS IS PLEASED TO OFFER YOU THESE ELECTRONICS CD-ROMS



GCSE ELECTRONICS

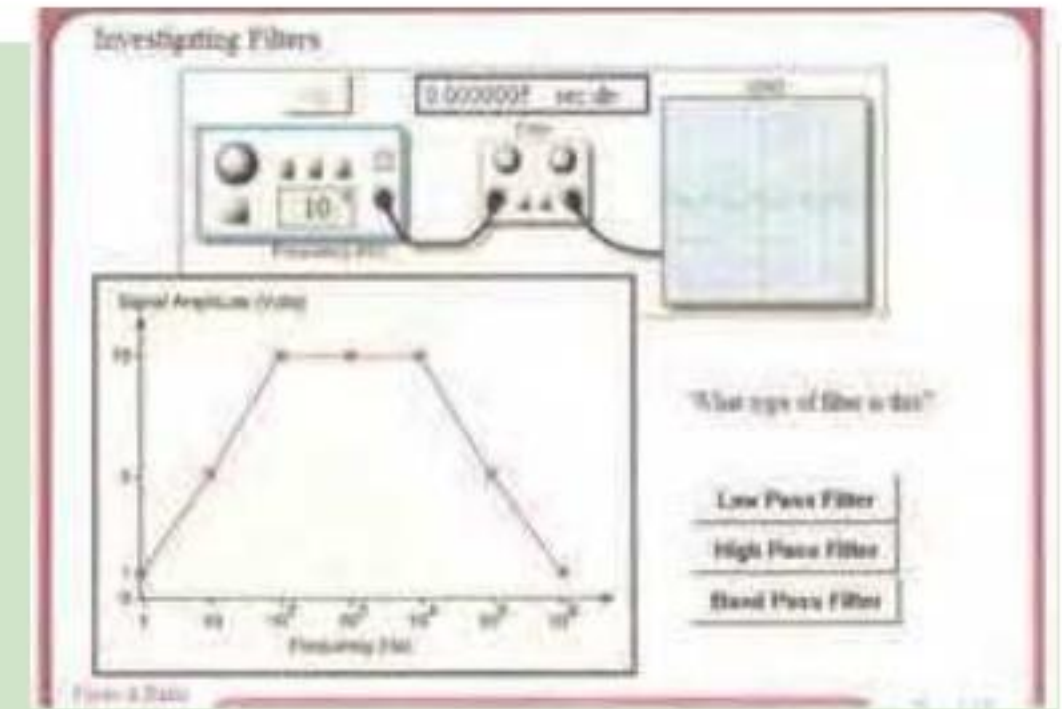
Suitable for any student who is serious about studying and who wants to achieve the best grade possible. Each program's clear, patient and structured delivery will aid understanding of electronics and assist in developing a confident approach to answering GCSE questions. The CD-ROM will be invaluable to anyone studying electronics, not just GCSE students.

- * Contains comprehensive teaching material to cover the National Curriculum syllabus
- * Regular exercises reinforce the teaching points
- * Retains student interest with high quality animation and graphics
- * Stimulates learning through interactive exercises
- * Provides sample examination questions with model solutions
- * Authored by practising teachers
- * Covers all UK examination board syllabuses
- * Caters for all levels of ability
- * Useful for self-tuition and revision

SUBJECTS COVERED

Electric Circuits – Logic Gates – Capacitors & Inductors – Relays – Transistors – Electric Transducers – Operational Amplifiers – Radio Circuits – Test Instruments

Over 100 different sections under the above headings



£12.50
inc. VAT and P&P

CIRCUIT WIZARD

Circuit Wizard is a revolutionary software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package. Two versions are available – Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

- * Circuit diagram design with component library (500 components Standard, 1500 components Professional)
- * Virtual instruments (4 Standard, 7 professional)
- * On-screen animation
- * Interactive circuit diagram simulation
- * True analogue/digital simulation
- * Simulation of component destruction
- * PCB Layout
- * Interactive PCB layout simulation
- * Automatic PCB routing
- * Gerber export
- * Multi-level zoom (25% to 1000%)
- * Multiple undo and redo
- * Copy and paste to other software
- * Multiple document support

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT. Professional **£75** plus VAT.

**From
£49.00**

TINA Design Suite V12

Analogue, Digital, Symbolic, RF, MCU and Mixed-Mode
Circuit Simulation and PCB Design with TINA

TINA Design Suite V12 is a powerful yet affordable software package for analysing, designing and real time testing analogue, digital, MCU, and mixed electronic circuits and their PCB layouts. You can also analyse RF, communication, optoelectronic circuits, test and debug microcontroller applications.

Enter and analyse any circuit up to 100 nodes (student), or 200 with the Basic (Hobbyist) version within minutes with TINA's easy-to-use schematic editor. Enhance your schematics by adding text and graphics. Choose components from the large library containing more than 10,000 manufacturer models. Analyse your circuit through more than 20 different analysis modes or with 10 high tech virtual instruments.

Present your results in TINA's sophisticated diagram windows, on virtual instruments, or in the live interactive mode where you can even edit your circuit during operation.

Customise presentations using TINA's advanced drawing tools to control text, fonts, axes, line width, colour and layout. You can create and print documents directly inside TINA or cut and paste your results into your favourite word processing or DTP package.

TINA includes the following Virtual Instruments: Oscilloscope, Function Generator, Multimeter, Signal Analyser/Bode Plotter, Network Analyser, Spectrum Analyser, Logic Analyser, Digital Signal Generator, XY Recorder.

This offer gives you a CD-ROM – the software will need registering (FREE) with Designsoft (TINA), details are given within the package.

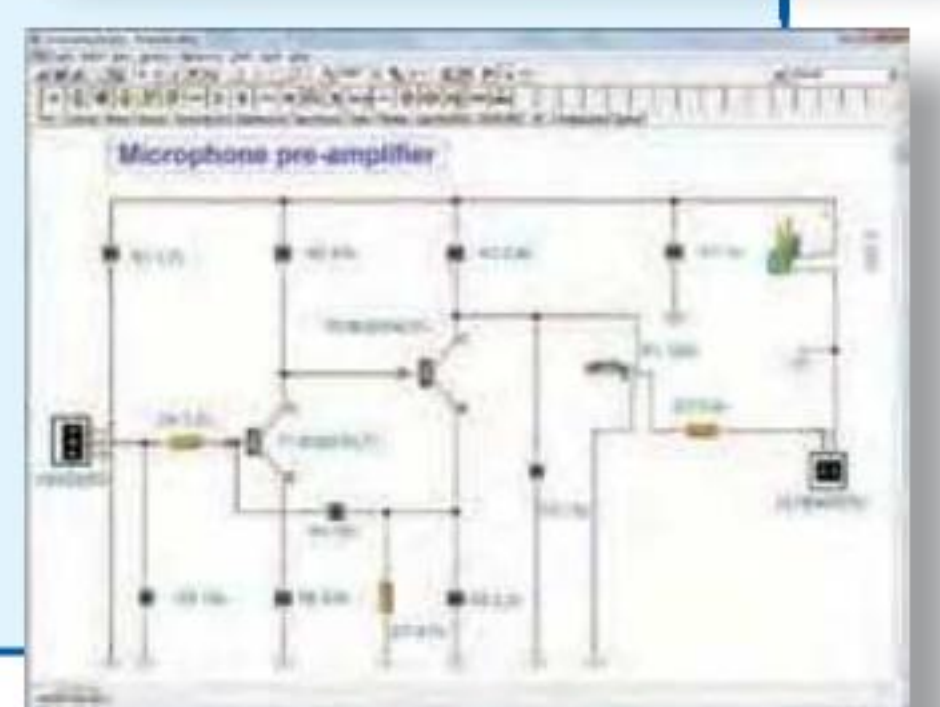
Get TINA 12 Design Suite (Hobbyist) for £129 or Student V12 version for £49

Prices include VAT and UK postage

+ get a 1 year free subscription for TINACloud the breakthrough cloud version of TINA which you can run on most operating systems and computers, including PCs, Macs, thin clients iPads and other tablets – even on many smart phones, smart TVs and e-book readers.

To order please either fill out and return the order form, or call us on **01202 880299**

Alternatively you can order via our secure online shop at: **www.epemag.com**



PICmicro TUTORIALS AND PROGRAMMING

HARDWARE

PICmicro Multiprogrammer Board and Development Board

Suitable for use with the three software packages listed below

This flexible PICmicro microcontroller programmer board and combination board allows students and professional engineers to learn how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40 pin devices from the 12, 16 and 18 series PICmicro ranges. For those who want to learn, choose one or all of the packages below to use with the hardware.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Compatible with the E-blocks range of accessories



£159.99 including VAT and postage (worldwide)

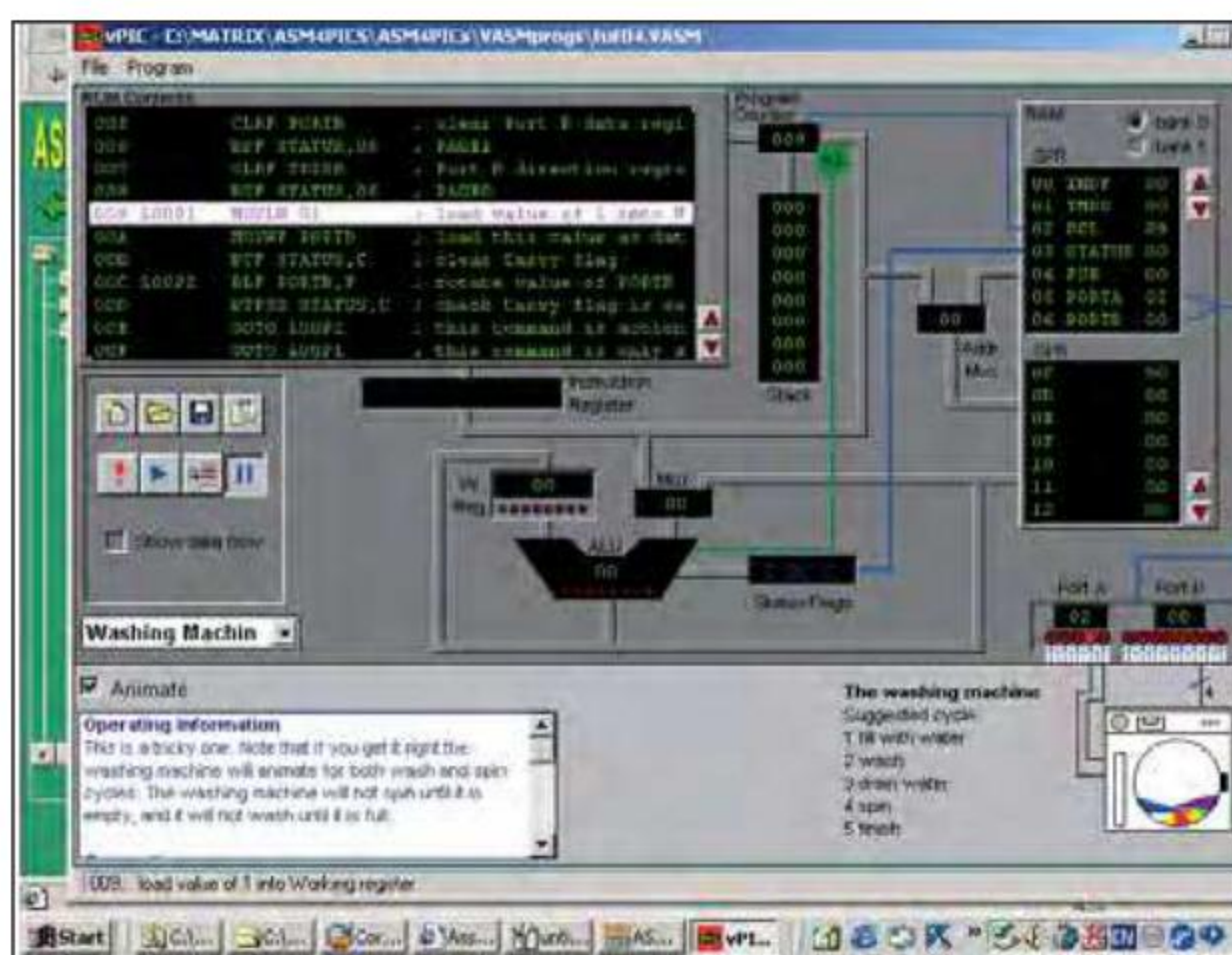
SOFTWARE

ASSEMBLY FOR PICmicro V7 (Formerly PICTutor)

Assembly for PICmicro microcontrollers V7.0 (previously known as PICTutor) by John Becker contains a complete course in programming the PIC16F84, 16F88 and 16F877a PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

- Comprehensive instruction through 45 tutorial sections
- Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator
- Tests, exercises and projects covering a wide range of PICmicro MCU applications
- Includes MPLAB assembler
- Visual representation of a PICmicro showing architecture and functions
- Expert system for code entry helps first time users
- Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.)
- Imports MPASM files.

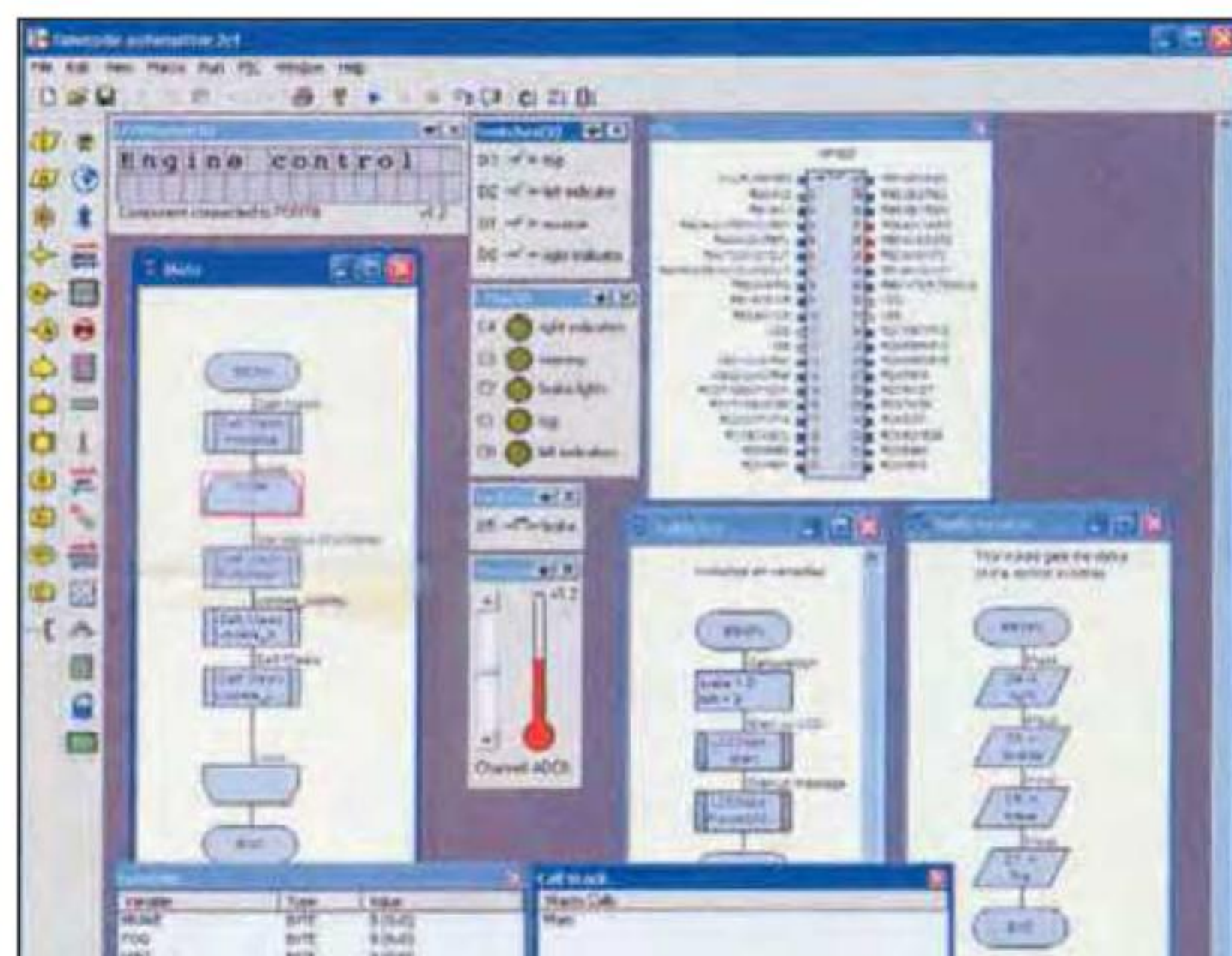


FLOWCODE FOR PICmicro V8

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces code for a wide range of devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Please note: Due to popular demand, Flowcode is now available as a download. Please include your email address and a username (of your choice) on your order. A unique download code will then be emailed to you.



PRICES

Prices for each of the CD-ROMs above are:
(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Single License£99 plus VAT

Site Licence£499 plus VAT

Flowcode Contact us for pricing
(choose PIC-8b, PIC-16b, PIC-32b, AVR/Arduino,ARM)

ELECTRONICS TEACH-IN 2

ELECTRONICS TEACH-IN 2 CD-ROM USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programming language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

CD-ROM

Order code ETI2 CD-ROM

£9.50

ELECTRONICS TEACH-IN 3

ELECTRONICS TEACH-IN 3 CD-ROM

The three sections of this CD-ROM cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of *Teach-In 3* are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on circuit design problems – from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The CD-ROM also contains the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial).

The *Teach-In 1* series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

CD-ROM

Order code ETI3 CD-ROM

£8.50

ELECTRONICS TEACH-IN 4

ELECTRONICS TEACH-IN 4 CD-ROM A BROAD-BASED INTRODUCTION TO ELECTRONICS.

The *Teach-In 4* CD-ROM covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the Diploma in Engineering, Level 2.

The CD-ROM also contains the full *Modern Electronics Manual*, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

CD-ROM

Order code ETI4 CD-ROM £8.99

ELECTRONICS TEACH-IN 5

ELECTRONICS TEACH-IN BUNDLE – FOR PARTS 3, 4 & 5

CD-ROM

Order code ETIB3 CD-ROM

£18.95

ORDERING ALL PRICES INCLUDE UK POSTAGE

Standard/Student/Basic (Hobbyist)
Version price includes postage to most countries
in the world EU residents outside the UK add £5 for
airmail postage per order



ELECTRONICS TEACH-IN 5 JUMP START

FREE
CD-ROM

15 design and build circuit projects dedicated to newcomers or those following courses in school and colleges. The projects are: Moisture Detector, Quiz Machine, Battery Voltage Checker, Solar-Powered Charger, Versatile Theft Alarm, Spooky Circuits, Frost Alarm, Mini Christmas Lights, iPod Speaker, Logic Probe, DC Motor Controller, Egg Timer, Signal Injector Probe, Simple Radio Receiver, Temperature Alarm.

PLUS:

PIC N' MIX – starting out with PIC Microcontrollers and PRACTICALLY SPEAKING – the techniques of project construction.

FREE CD-ROM – The free CD-ROM is the complete *Teach-In 2* book providing a practical introduction to PIC Microprocessors plus MikroElektronika, Microchip and L-Tek PoScope software.

160 Pages

Order code ETI5

£8.99

Single License and Site License Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add VAT at 20% or provide your official VAT registration number).

Send your order to:
Electron Publishing Limited
113 Lynwood Drive
Wimborne
Dorset BH21 1UU

To order by phone call: **01202 880299**

Goods are normally sent within seven days

E-mail: shop@electronpublishing.com

Online shop:

www.electronpublishing.com

Please send me: **CD-ROM ORDER FORM**

- ☐ Assembly for PICmicro V6
☐ 'C' for 16 Series PICmicro V6

- Version required:
☐ Single Licence
☐ Site licence

Note: The software on each version is the same, only the licence for use varies.

- ☐ PICmicro Multiprogrammer Board and Development Board (hardware)

- ☐ Circuit Wizard – Standard
☐ Circuit Wizard – Professional

- ☐ GCSE Electronics

- ☐ TINA Design Suite V11 Basic (Hobbyist)

- ☐ TINA Design Suite V11 (Student)

- ☐ Teach-In 2
☐ Teach-In 3
☐ Teach-In 4
☐ Teach-In Bundle
(3, 4 and 5)

Full name

Address

..... Post code Tel

Email:

☐ I enclose cheque/PO in £ sterling payable to Practical Electronics for £

☐ Please charge my Visa/Mastercard: £

Valid From: Card expiry date:

Card No:

Card Security Code

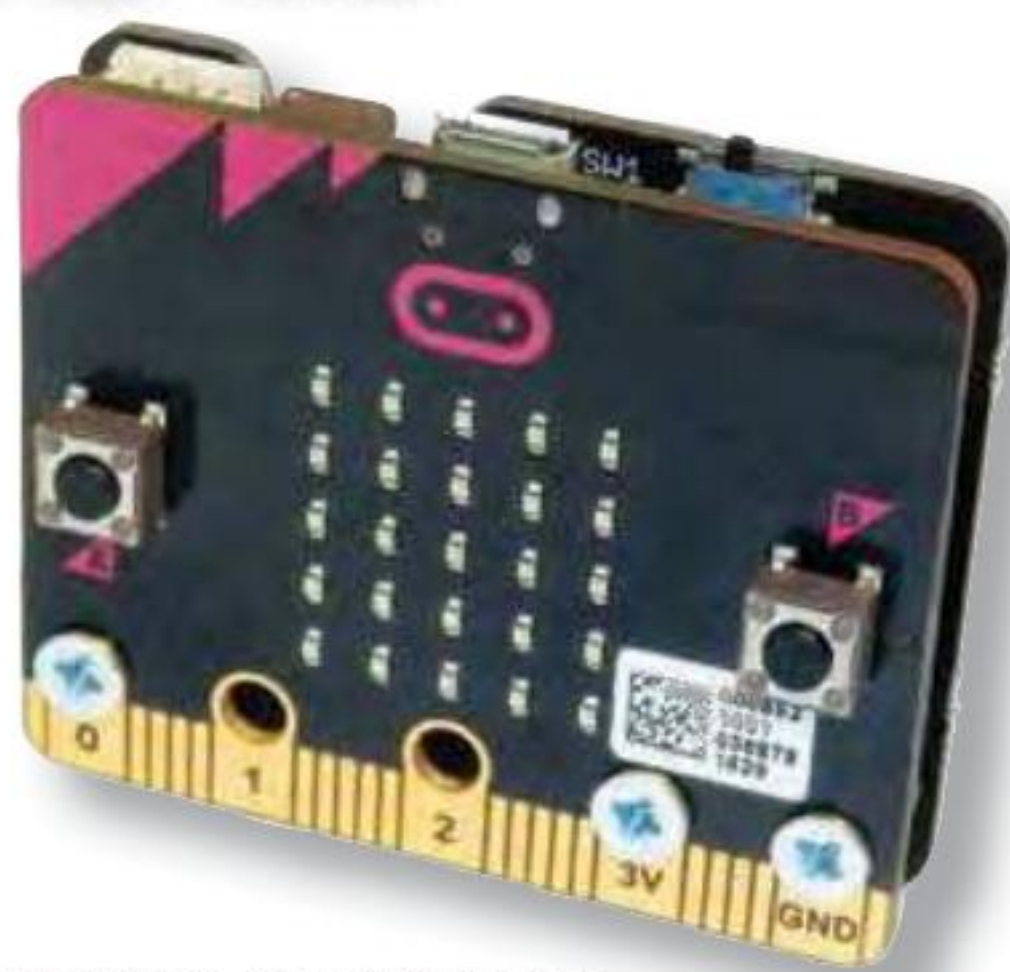
(The last 3 digits on or just under the signature strip)



DIRECT BOOK SERVICE

Teach-In 2017

Introducing the BBC micro:bit



PYTHON CODING ON THE BBC MICRO:BIT

Jim Gatenby

Python is the leading programming language, easy to learn and widely used by professional programmers. This book uses MicroPython, a version of Python adapted for the BBC Micro:bit.

Among the many topics covered are: main features of the BBC micro:bit including a simulation in a web browser screen; various levels of programming languages; Mu Editor for writing, saving and retrieving programs, with sample programs and practice exercises; REPL, an interactive program for quickly testing lines of code; scrolling messages, creating and animating images on the micro:bit's LEDs; playing and creating music, sounds and synthesized speech; using the on-board accelerometer to detect movement of the micro:bit on three axes; glossary of computing terms.

This book is written using plain English, avoids technical jargon wherever possible and covers many of the coding instructions and methods which are common to most programming languages. It should be helpful to beginners of any age, whether planning a career in computing or writing code as an enjoyable hobby.

118 Pages

Order code PYTH MBIT

£7.99



GETTING STARTED WITH THE BBC MICRO:BIT

Mike Tooley

Not just an educational resource for teaching youngsters coding, the BBC micro:bit is a tiny low cost, low-profile ARM-based single-board computer. The board measures 43mm x 52mm but despite its diminutive footprint it has all the features of a fully fledged microcontroller together with a simple LED matrix display, two buttons, an accelerometer and a magnetometer.

Mike Tooley's book will show you how the micro:bit can be used in a wide range of applications from simple domestic gadgets to more complex control systems such as those used for lighting, central heating and security applications. Using Microsoft Code Blocks, the book provides a progressive introduction to coding as well as interfacing with sensors and transducers.

Each chapter concludes with a simple practical project that puts into practice what the reader has learned. The featured projects include an electronic direction finder, frost alarm, reaction tester, battery checker, thermostatic controller and a passive infrared (PIR) security alarm.

No previous coding experience is assumed, making this book ideal for complete beginners as well as those with some previous knowledge. Self-test questions are provided at the end of each chapter, together with answers at the end of the book. So whatever your starting point, this book will take you further along the road to developing and coding your own real-world applications.

108 Pages

Order code BBC MBIT

£7.99

THEORY AND REFERENCE

PRACTICAL ELECTRONICS HANDBOOK – 6th Ed

Ian Sinclair

440 pages

Order code NE21

£33.99

STARTING ELECTRONICS – 4th Ed

Keith Brindley

296 pages

Order code ELSEV100

£18.99

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS – Updated version

Mike Tooley

400 pages

Order code TF43

£32.99

FUNDAMENTAL ELECTRICAL AND ELECTRONIC PRINCIPLES – 3rd Ed

C.R. Robertson

368 pages

Order code TF47

£21.99

A BEGINNER'S GUIDE TO TTL DIGITAL ICs

Robert Penfold

142 pages

OUT OF PRINT BP332

£5.45

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS

Owen Bishop

228 pages

Order code NE35

£36.99

The books listed here have been selected by the *Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door.

FOR A FULL DESCRIPTION OF THESE BOOKS AND CD-ROMS SEE THE SHOP ON OUR WEBSITE

www.electronpublishing.com

All prices include UK postage

MICROPROCESSORS

INTERFACING PIC MICROCONTROLLERS – 2nd Ed

Martin Bates

298 pages

Order code NE48

£34.99

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24

Lucio Di Jasio (Application Segments Manager, Microchip, USA)

496 pages + CD-ROM

Order code NE45

£38.00

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – 2nd Ed

John Crisp

222 pages

Order code NE31

£29.99

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – 3rd Ed

John Morton

270 pages

Order code NE36

£25.00

PIC IN PRACTICE – 2nd Ed

David W. Smith

308 pages

Order code NE39

£24.99

MICROCONTROLLER COOKBOOK

Mike James

240 pages

Order code NE26

£36.99

BOOK ORDERING DETAILS

All prices include UK postage.

For postage, add £3 per book to Europe, £4 for rest of the world per book.

CD-ROM prices include VAT and/or postage to anywhere in the world.

Send a cheque, (£ sterling only) made payable to: **Practical Electronics** or credit card details (Visa or Mastercard) to:

**Electron Publishing Limited,
113 Lynwood Drive, Wimborne, Dorset BH21 1UU**

Books are normally sent within seven days of receipt of order.

Please check price (see latest issue of Practical Electronics or website) before ordering from old lists.

For a full description of these books please see the shop on our website.

Tel: 01202 880299 – Email: shop@electronpublishing.com

Order from our online shop at: www.electronpublishing.com



ARDUINO

Teach-In 2016

See opposite for our popular introduction to the Arduino



ARDUINO FOR DUMMIES John Nussey

Arduino is no ordinary circuit board. Whether you're an artist, a designer, a programmer, or a hobbyist, Arduino lets you learn about and play with electronics. You'll discover how to build a variety of circuits that can sense or control real-world objects, prototype your own product, and even create interactive artwork. This handy guide is exactly what you need to build your own Arduino project – what you make is up to you!

- **Learn by doing** – start building circuits and programming your Arduino with a few easy examples – right away!
- **Easy does it** – work through Arduino sketches line by line, and learn how they work and how to write your own.
- **Solder on!** – don't know a soldering iron from a curling iron? No problem! You'll learn the basics and be prototyping in no time.
- **Kitted out** – discover new and interesting hardware to turn your Arduino into anything from a mobile phone to a Geiger counter.
- **Become an Arduino savant** – find out about functions, arrays, libraries, shields and other tools that let you take your Arduino project to the next level
- **Get social** – teach your Arduino to communicate with software running on a computer to link the physical world with the virtual world

438 Pages **Order code ARDDUM01** £19.99



EXPLORING ARDUINO Jeremy Blum

Arduino can take you anywhere. This book is the roadmap. Exploring Arduino shows how to use the world's most popular microcontroller to create cool, practical, artistic and educational projects. Through lessons in electrical engineering, programming and human-computer interaction, this book walks you through specific, increasingly complex projects, all the while providing best practices that you can apply to your own projects once you've mastered these. You'll acquire valuable skills – and have a whole lot of fun.

- **Explore** the features of commonly used Arduino boards
- **Use** Arduino to control simple tasks or complex electronics
- **Learn** principles of system design, programming and electrical engineering
- **Discover** code snippets, best practices and system schematics you can apply to your original projects
- **Master** skills you can use for engineering endeavours in other fields and with different platforms

357 Pages **Order code EXPARD01** £26.99

COMPUTING AND ROBOTICS

NEWNES INTERFACING COMPANION Tony Fischer-Cripps

295 pages **Order code NE38** £41.00

HOW TO BUILD A COMPUTER MADE EASY Robert Penfold

120 pages **Order code BP707** £8.49

EASY PC CASE MODDING Robert Penfold

192 pages + CD-ROM **Order code BP542** £8.99

FREE DOWNLOADS TO PEP-UP AND PROTECT YOUR PC Robert Penfold

128 pages **Order code BP722** £7.99

WINDOWS XP EXPLAINED N. Kantaris and P.R.M. Oliver

264 pages **Order code BP514** £7.99

THE INTERNET – TWEAKS, TIPS AND TRICKS Robert Penfold

128 pages **Order code BP721** £7.99

eBAY – TWEAKS, TIPS AND TRICKS Robert Penfold

128 pages **Order code BP716** £7.50

AN INTRODUCTION TO eBAY FOR THE OLDER GENERATION Cherry Nixon

120 pages **Order code BP709** £8.49

HOW TO FIX YOUR PC PROBLEMS Robert Penfold

128 pages **Order code BP705** £8.49

AN INTRODUCTION TO WINDOWS VISTA P.R.M. Oliver and N. Kantarris

120 pages **Order code BP703** £8.49

WINDOWS 8.1 EXPLAINED

180 Pages **Order code BP747** £10.99

AN INTRODUCTION TO THE NEXUS 7

118 Pages **Order code BP744** £8.99

COMPUTING FOR THE OLDER GENERATION Jim Gatenby

308 pages **Order code BP601** £8.99

ANDROIDS, ROBOTS AND ANIMATRONICS Second Edition – John Iovine

224 pages **Order code MGH1** £16.99

ROBOT BUILDERS COOKBOOK Owen Bishop

366 pages **Order code NE46** £26.00

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS Robert Penfold

288 pages + **Order code BP901** £14.99

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS Robert Penfold

298 pages **Order code BP902** £14.99

HOW TO FIX YOUR PC PROBLEMS Robert Penfold

128 pages **Order code BP705** £8.49

WINDOWS 7 – TWEAKS, TIPS AND TRICKS Andrew Edney

120 pages **Order code BP708** £8.49

GETTING STARTED IN COMPUTING FOR THE OLDER GENERATION Jim Gatenby

120 pages **Order code BP704** £8.49

WINDOWS 8.1 EXPLAINED Noel Kantaris

180 Pages **Order code BP747** £10.99

COMPUTING WITH A LAPTOP FOR THE OLDER GENERATION Robert Penfold

120 pages **Order code BP702** £8.49

AN INTRODUCTION TO EXCEL SPREADSHEETS Jim Gatenby

18 pages **Order code BP701** £8.49

KINDLE FIRE HDX EXPLAINED

118 Pages **Order code BP743** £8.99

AUDIO & VIDEO

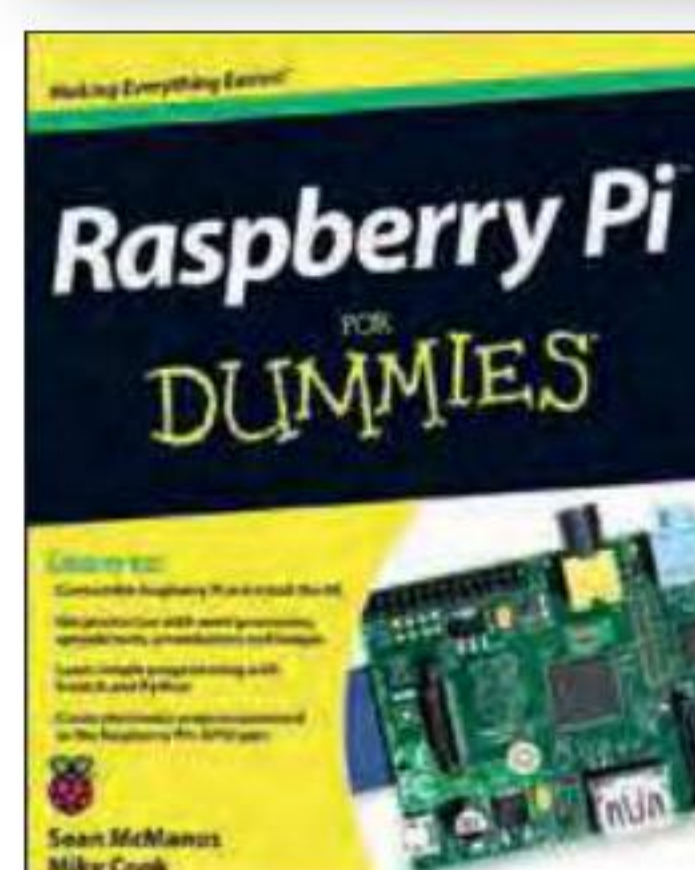
VALVE AMPLIFIERS – 4th Ed Morgan Jones

288 pages **Order code ELSEV33** £46.99

BUILDING VALVE AMPLIFIERS Morgan Jones

368 pages **Order code NE40** £29.00

RASPBERRY PI



RASPBERRY Pi FOR DUMMIES Sean McManus and Mike Cook

Write games, compose and play music, even explore electronics – it's easy as Pi! The Raspberry Pi offers a plethora of opportunities, and this great resource guides you step-by-step, from downloading, copying, and installing the software to learning about Linux and finding cool new programs for work, photo editing, and music. You'll discover how to write your own Raspberry Pi programs, create fun games, and much more!

Open this book and find:

What you can do with Python; Ways to use the Raspberry Pi as a productivity tool; How to surf the web and manage files; Secrets of Sonic Pi music programming; A guide to creating animations and arcade games; Fun electronic games you can build; How to build a 3D maze in Minecraft; How to play music and videos on your Raspberry Pi.

400 Pages **Order code RPiDUM01** £17.99

RASPBERRY Pi MANUAL: A practical guide to the revolutionary small computer

176 pages **Order code H001** £17.99

RASPBERRY Pi USER-GUIDE – 4th Ed

262 pages **Order code JW001** £20.90

PROGRAMMING THE RASPBERRY Pi

192 pages **Order code MGH4** £10.99

GETTING STARTED WITH RASPBERRY Pi

164 pages **Order code OR01** £11.50

TEACH-IN BOOKS

ELECTRONICS TEACH-IN 6



ONLY AVAILABLE ON CD-ROM

ELECTRONICS TEACH-IN 6 A COMPREHENSIVE GUIDE TO RASPERRY PI Mike & Richard Tooley

Teach-In 6 contains an exciting series of articles that provides a complete introduction to the Raspberry Pi, the low-cost computer that has taken the education and computing world by storm.

This latest book in our Teach-In series will appeal to electronic enthusiasts and computer buffs wanting to get to grips with the Raspberry Pi.

Anyone considering what to do with their Pi, or maybe they have an idea for a project but don't know how to turn it into reality, will find Teach-In 6 invaluable. It covers: Programming, Hardware, Communications, Pi Projects, Pi Class, Python Quickstart, Pi World, and Home Baking.

The CD-ROM also contains all the necessary software for the series so that readers can get started quickly and easily with the projects and ideas covered.

160 Pages

Order code ETI6

£8.99

ELECTRONICS TEACH-IN 7 (Includes free CD-ROM)



RUNNING LOW – ORDER NOW!

ELECTRONICS TEACH-IN 7 DISCRETE LINEAR CIRCUIT DESIGN Mike & Richard Tooley

Teach-In 7 is a complete introduction to the design of analogue electronic circuits. Ideal for everyone interested in electronics as a hobby and for those studying technology at schools and colleges. Supplied with a free cover-mounted CD-ROM containing all the circuit software for the course, plus demo CAD software for use with the Teach-In series.

Discrete Linear Circuit Design* Understand linear circuit design* Learn with 'TINA' – modern CAD software* Design simple, but elegant circuits* Five projects to build: Pre-amp, Headphone Amp, Tone Control, VU-meter, High Performance Audio Power Amp.

PLUS

Audio Out – an analogue expert's take on specialist circuits
Practically Speaking – the techniques of project building

160 Pages

Order code ETI7

£8.99

ELECTRONICS TEACH-IN 8



ONLY AVAILABLE ON CD-ROM

ELECTRONICS TEACH-IN 8 INTRODUCING THE ARDUINO Mike & Richard Tooley

Hardware – learn about components and circuits; Programming – powerful integrated development system; Microcontrollers – understand control operations; Communications – connect to PCs and other Arduinos.

This exciting series has been designed for electronics enthusiasts who want to get to grips with the inexpensive, immensely popular Arduino microcontroller, as well as coding enthusiasts who want to explore hardware and interfacing. Teach-In 8 will provide a one-stop source of ideas and practical information.

The Arduino offers a remarkably effective platform for developing a huge variety of projects; from operating a set of Christmas tree lights to remotely controlling a robotic vehicle through wireless or the Internet. Teach-In 8 is based around a series of practical projects with plenty of information to customise each project.

This book also includes *PIC n' Mix*: PICs and the PICKit 3 - A Beginners guide by Mike O'Keefe and *Circuit Surgery* by Ian Bell - State Machines part 1 and 2.

The CD-ROM includes files for Teach-In 8 plus Microchip MPLAB IDE XC8 8-bit Compiler and PICKit 3 User Guide. Also included is Lab-Nation Smartscope software.

160 Pages

Order code ETI8

£8.99

**VISIT OUR WEBSITE FOR MORE BOOKS
AND FAST, EASY ONLINE ORDERING**
www.electronpublishing.com

BOOK ORDER FORM

Full name:

Address:

Post code: Telephone No:

Email:

☐ I enclose cheque/PO payable to Practical Electronics for £

☐ Please charge my card £ Card expiry date:

Card Number

Valid From Date Card Security Code (The last three digits on or just below the signature strip)

Please send book order codes:

.....

Please continue on separate sheet of paper if necessary

THE BASIC SOLDERING GUIDE

**LEARN TO SOLDER
SUCCESSFULLY!**
ALAN WINSTANLEY

The No.1 resource for learning all the basic aspects of electronics soldering by hand.

With more than 80 high quality colour photographs, this book explains the correct choice of soldering irons, solder, fluxes and tools. The techniques of how to solder and desolder electronic components are then explained in a clear, friendly and non-technical fashion so you'll be soldering successfully in next to no time! The book also includes sections on reflow soldering and desoldering techniques, potential hazards, useful resources and a very useful troubleshooting guide.

Also ideal for those approaching electronics from other industries, the *Basic Soldering Guide Handbook* is the best resource of its type, and thanks to its excellent colour photography and crystal clear text, the art of soldering can now be learned by everyone!

86 Pages

Order code AW1

£9.99

Practical Electronics PCB SERVICE

PROJECT	CODE	PRICE
MAY 2020		
Ultra-low-distortion Preamplifier Input Selector	01111112	11.25
Ultra-low-distortion Preamplifier pushbutton Input Selector	01111113	
433MHz Wireless Data Repeater	15004191	8.50
Bridge-mode Adaptor for Amplifier	01105191	7.95
iCEstick VGA Terminal	02103191	4.95
Analogue noise with tilt control	AO-0520-01	7.95
Audio Spectrum Analyser	PM-0520-01	8.95
APRIL 2020		
Flip-dot Display black coil board.....	19111181	£14.95
Flip-dot Display black pixels	19111182	
Flip-dot Display black frame	19111183	
Flip-dot Display green driver board.....	19111184	
MARCH 2020		
Diode Curve Plotter	04112181	£10.95
Steam Train Whistle / Diesel Horn Sound Generator	09106181	£8.50
Universal Passive Crossover (one off)	UPC0320	£12.50
Crossover component set for Wavecor speaker (one off).....	WAVXO (see website)	
FEBRUARY 2020		
Motion-Sensing 12V Power Switch	05102191	£5.95
USB Keyboard / Mouse Adaptor.....	24311181	£8.50
DSP Active Crossover (ADC)	01106191	£29.95
DSP Active Crossover (DAC) x2	01106192	
DSP Active Crossover (CPU)	01106193	
DSP Active Crossover (Power/routing).....	01106194	
DSP Active Crossover (Front panel).....	01106195	
DSP Active Crossover (LCD).....	01106196	
JANUARY 2020		
Isolated Serial Link	24107181	£8.50
DECEMBER 2019		
Extremely Sensitive Magnetometer.....	04101011	£16.75
Four-channel High-current DC Fan and Pump Controller ...	05108181	£8.75
Useless Box	08111181	£11.50
NOVEMBER 2019		
Tinnitus & Insomnia Killer (Jaycar case – see text)	01110181	£8.75
Tinnitus & Insomnia Killer (Altronics case – see text).....	01110182	£8.75
OCTOBER 2019		
Programmable GPS-synced Frequency Reference	04107181	£11.50
Digital Command Control Programmer for Decoders.....	09107181	£8.75
Opto-isolated Mains Relay (main board)	10107181	£11.50
Opto-isolated Mains Relay (2 x terminal extension board)...	10107182	
AUGUST 2019		
Brainwave Monitor.....	25108181	£12.90
Super Digital Sound Effects Module.....	01107181	£5.60
Watchdog Alarm	03107181	£8.00
PE Theremin (three boards: pitch, volume, VCA)	PETX0819	£19.50
PE Theremin component pack (see p.56, August 2019) ...	PETY0819	£15.00
JULY 2019		
Full-wave 10A Universal Motor Speed Controller.....	10102181	£12.90
Recurring Event Reminder	19107181	£8.00
Temperature Switch Mk2.....	05105181	£10.45
JUNE 2019		
Arduino-based LC Meter	04106181	£8.00
USB Flexitimer.....	19106181	£10.45

PROJECT	CODE	PRICE
MAY 2019		
2x 12V Battery Balancer	14106181	£5.60
Deluxe Frequency Switch.....	05104181	£10.45
USB Port Protector.....	07105181	£5.60
APRIL 2019		
Heater Controller	10104181	£14.00
MARCH 2019		
10-LED Bargraph Main Board	04101181	£11.25
+Processing Board	04101182	£8.60
FEBRUARY 2019		
1.5kW Induction Motor Speed Controller.....	10105122	£35.00
NOVEMBER 2018		
Super-7 AM Radio Receiver.....	06111171	£27.50
OCTOBER 2018		
6GHz+ Touchscreen Frequency Counter	04110171	£12.88
Two 230VAC MainsTimers	10108161	£12.88
	10108162	
SEPTEMBER 2018		
3-Way Active Crossover	01108171	£22.60
Ultra-low-voltage Mini LED Flasher.....	16110161	£5.60
AUGUST 2018		
Universal Temperature Alarm	03105161	£7.05
Power Supply For Battery-Operated Valve Radios	18108171	£27.50
	18108172	
	18108173	
	18108174	
JULY 2018		
Touchscreen Appliance Energy Meter – Part 1	04116061	£17.75
Automotive Sensor Modifier	05111161	£12.88
JUNE 2018		
High Performance 10-Octave Stereo Graphic Equaliser...	01105171	£15.30
MAY 2018		
High Performance RF Prescaler.....	04112162	£10.45
Micromite BackPack V2.....	07104171	£10.45
Microbridge.....	24104171	£5.60
APRIL 2018		
Spring Reverberation Unit	01104171	£15.30
DDS Sig Gen Lid	Black	£8.05
DDS Sig Gen Lid	Blue	£7.05
DDS Sig Gen Lid	Clear	£8.05
MARCH 2018		
Stationmaster Main Board	09103171	£17.75
+ Controller Board	09103172	
SC200 Amplifier Module – Power Supply.....	01109111	£16.45
FEBRUARY 2018		
GPS-Synchronised Analogue Clock Driver	04202171	£12.88
High-Power DC Motor Speed Controller – Part 2		
+ Control Board.....	11112161	£12.88
+ Power Board	11112162	£15.30
JANUARY 2018		
High-Power DC Motor Speed Controller – Part 1	11112161	£12.88
Build the SC200 Amplifier Module	01108161	£12.88

PCBs for most recent *PE/EPE* constructional projects are available. From the July 2013 issue onwards, PCBs with eight-digit codes have silk screen overlays and, where applicable, are double-sided, have plated-through holes, and solder mask. They are similar to photos in the project articles. Earlier PCBs are likely to be more basic and may not include silk screen overlay, be single-sided, lack plated-through holes and solder mask.

Always check price and availability in the latest issue or online. A large number of older boards are listed for ordering on our website.

In most cases we do not supply kits or components for our projects. For older projects it is important to check the availability of all components before purchasing PCBs.

Back issues of articles are available – see Back Issues page for details.

PROJECT	CODE	PRICE
JULY 2016		
Driveway Monitor – Detector Unit.....	15105151	£11.80
Driveway Monitor – Receiver Unit	15105152	£7.50
USB Charging Points.....	18107151	£5.00
JUNE 2016		
Infrasound Snooper.....	04104151	£7.50
Audio Signal Injector and Tracer	04106151	£9.64
Audio Signal Injector and Tracer – Demodulator Board	04106152	£5.36
Audio Signal Injector and Tracer – Shield Board.....	04106153	£7.48
Champion Preamp.....	01109121/22	£8.29
MAY 2016		
2-Channel Balanced Input Attenuator for Audio		
Analysers and Digital Scopes – Main Board	04105151	£16.40
Analysers and Digital Scopes – Front Panel.....	04105152	£20.75
Analysers and Digital Scopes – Rear Panel.....	04105153	
Appliance Earth Leakage Tester – Main Board	04203151	£16.40
Appliance Earth Leakage Tester – Insulation Board.....	04203152	
Appliance Earth Leakage Tester – Front Panel.....	04203153	£16.40
4-Output Universal Voltage Regulator	18105151	£7.50

PE/EPE PCB SERVICE

[illegible]

You can also order PCBs by phone, email or via the shop on our website: www.electronpublishing.com

No need to cut your issue – a copy of this form is just as good!



ETI BUNDLE (1) Teach-In 3, 4 and 5 – all on CD-ROM – only £18.95

ELECTRONICS TEACH-IN 3 – CD-ROM

Mike & Richard Tooley

The three sections of the *Teach-In 3* CD-ROM cover a huge range of subjects that will interest everyone involved in electronics – from newcomers to the hobby and students to experienced constructors and professionals.

The first section (80 pages) is dedicated to *Circuit Surgery*, EPE/PE's regular clinic dealing with readers' queries on circuit design problems – from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers hands-on aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and identifying components is covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by readers.

The CD-ROM also contains the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge and TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial).

The *Teach-In 1* series covers everything from electric current through to microprocessors and microcontrollers, and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

ELECTRONICS TEACH-IN 4 – CD-ROM A BROAD-BASED INTRODUCTION TO ELECTRONICS

Mike & Richard Tooley

The *Teach-In 4* CD-ROM covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the Diploma in Engineering, Level 2.

The CD-ROM also contains the full *Modern Electronics Manual*, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to anyone interested in learning about electronics – hobbyists, students or professionals.



ELECTRONICS TEACH-IN 5 – CD-ROM JUMP START

Mike & Richard Tooley

15 design and build circuit projects for newcomers or those following courses in school and colleges.

The projects are: ■ Moisture Detector ■ Quiz Machine ■ Battery Voltage Checker ■ Solar-Powered Charger ■ Versatile Theft Alarm ■ Spooky Circuits ■ Frost Alarm ■ Mini Christmas Lights ■ iPod Speaker ■ Logic Probe ■ DC Motor Controller ■ Egg Timer ■ Signal Injector Probe ■ Simple Radio Receiver ■ Temperature Alarm.

PLUS

PIC'n' Mix – starting out with the popular range of PIC microcontrollers and *Practically Speaking* – tips and techniques for project construction.

The CD-ROM also contains:

- Complete *Teach-In 2* book, a practical introduction to PIC microprocessors
- MikroElektronika, Microchip and L-Tek PoScope software.



Three Teach-ins for the great price of
£18.95

PLUS you also get the contents of the
free CD-ROM from each issue...

... so that's another TWO Teach-Ins and
The Full Modern Electronics Manual!

What a Bargain!!

ETI BUNDLE (2) Teach-In 6, 7 and 8 – all on CD-ROM – only £18.95

ELECTRONICS TEACH-IN 6 – CD-ROM A COMPREHENSIVE GUIDE TO RASPBERRY PI

Mike & Richard Tooley

Teach-In 6 contains an exciting series of articles that provides a complete introduction to the Raspberry Pi, the low cost computer that has taken the education and computing world by storm.

This latest book in our *Teach-In* series will appeal to electronics enthusiasts and computer buffs who want to get to grips with the Raspberry Pi.

Teach-In 6 is for anyone searching for ideas to use their Pi, or who has an idea for a project but doesn't know how to turn it into reality. This book will prove invaluable for anyone fascinated by the revolutionary Pi. It covers:

- Pi programming
- Pi hardware
- Pi communications
- Pi Projects
- Pi Class
- Python Quickstart
- Pi World
- ...and much more!

The *Teach-In 6* CD-ROM also contains all the necessary software for the series, so that readers and circuit designers can get started quickly and easily with the projects and ideas covered.



ELECTRONICS TEACH-IN 7 – CD-ROM DISCRETE LINEAR CIRCUIT DESIGN

Mike & Richard Tooley

Teach-In 7 is a complete introduction to the design of analogue electronic circuits. It is ideal for everyone interested in electronics as a hobby and for those studying technology at schools and colleges. The CD-ROM also contains all the circuit software for the course, plus demo CAD software for use with the *Teach-In* series.

- Discrete Linear Circuit Design
- Understand linear circuit design
- Learn with 'TINA' – modern CAD software
- Design simple, but elegant circuits
- Five projects to build:
 - i) Pre-amp
 - ii) Headphone Amp
 - iii) Tone Control
 - iv) VU-meter
 - v) High Performance Audio Power Amp.

PLUS

Audio Out – an analogue expert's take on specialist circuits

Practically Speaking – the techniques of project building.



ELECTRONICS TEACH-IN 8 – CD-ROM INTRODUCING THE ARDUINO

Mike & Richard Tooley

Hardware: learn about components and circuits
Programming: powerful integrated development system
Microcontrollers: understand control operations
Communications: connect to PCs and other Arduinos.

Teach-In 8 is an exciting series designed for electronics enthusiasts who want to get to grips with the inexpensive, popular Arduino microcontroller, as well as coding enthusiasts who want to explore hardware and interfacing. It will provide a one-stop source of ideas and practical information.

The Arduino offers a truly effective platform for developing a huge variety of projects; from operating a set of Christmas tree lights to remotely controlling a robotic vehicle through wireless or the Internet.

Teach-In 8 is based around a series of practical projects with plenty of information for customisation.

This book also includes *PIC n' Mix*: 'PICs and the PICkit 3 – A Beginners guide' by Mike O'Keefe and *Circuit Surgery* by Ian Bell – 'State Machines part 1 and 2'.

The CD-ROM includes the files for:

- *Teach-In 8*
- Microchip MPLAB IDE XC8 8-bit compiler
- PICkit 3 User Guide
- Lab-Nation Smartscope software.



ORDER YOUR BUNDLE TODAY!

JUST CALL 01202 880299 – OR VISIT www.electronpublishing.com

CLASSIFIED ADVERTISING



Practical Electronics

If you want your advertisements to be seen by the largest readership at the most economical price then our classified page offers excellent value. The rate for semi-display space is £10 (+VAT) per centimetre high, with a minimum height of 2.5cm. All semi-display adverts have a width of 5.5cm. The prepaid rate for classified adverts is 40p (+VAT) per word (minimum 12 words).

Cheques are made payable to 'Practical Electronics'. **VAT must be added.** Advertisements with remittance should be sent to: Practical Electronics, 113 Lynwood Drive, Wimborne, Dorset, BH21 1UU.

Tel 01202 880299 Email: stewart.kearn@wimborne.co.uk

For rates and further information on display and classified advertising please contact our Advertisement Manager, Stewart Kearn – see below.

Practical Electronics reaches more UK readers than any other UK monthly hobby electronics magazine. Our sales figures prove it.

We have been the leading monthly magazine in this market for the last twenty-seven years.

BOWOOD ELECTRONICS LTD

Suppliers of Electronic Components

www.bowood-electronics.co.uk

Unit 10, Boythorpe Business Park, Dock Walk, Chesterfield, Derbyshire S40 2QR. Sales: 01246 200 222

Send large letter stamp for Catalogue

The British Amateur Electronic Club at:

baec.tripod.com

Has many interesting articles on computers; digital electronics and analogue electronics.



COAST ELECTRONICS

BREAKOUTS-COMPONENTS-
CONTRACT DESIGN-3D PRINTER PARTS-
MUSICAL-MICROCONTROLLERS
WWW.COASTELECTRONICS.CO.UK

MISCELLANEOUS

VALVES AND ALLIED COMPONENTS IN STOCK. Phone for free list. Valves, books and magazines wanted. Geoff Davies (Radio), tel. 01788 574774.

PIC DEVELOPMENT KITS, DTMF kits and modules, CTCSS Encoder and Decoder/Display kits. Visit www.cstech.co.uk

Electrical Industries Charity (EIC)

We help people working in the electrical, electronics and energy community as well as their family members and retirees.

We use workplace programmes that give the industry access to financial grants and a comprehensive range of free and confidential services.

www.electricalcharity.org



Andrew Kenny – Qualified Patent Agent
EPO UKIPO USPTO

Circuits Electric Machinery Mechatronics

Web: www.akennypatentm.com

Email: Enquiries@akennypatentm.com

Tel: 0789 606 9725

ADVERTISING INDEX

CRICKLEWOOD ELECTRONICS	47
ESR ELECTRONIC COMPONENTS	3
HAMMOND ELECTRONICS Ltd	8
JPG ELECTRONICS	80
MICROCHIP	Cover (ii), Cover (iii), 5
PEAK ELECTRONIC DESIGN	Cover (iv)
POLABS D.O.O.	14
QUASAR ELECTRONICS	2
STEWART OF READING	9
TAG-CONNECT	3

Advertisement offices

Electron Publishing Ltd
113 Lynwood Drive
Merley
Wimborne,
Dorset BH21 1UU

Tel 01202 880299

Fax 01202 843233

Email pe@electronpublishing.com

Web www.electronpublishing.com

For editorial contact details see page 7.

Next Month – in the June issue

AM/FM/CW Scanning HF/VHF RF Signal Generator

This low-cost, easy-to-build and user-friendly *RF Signal Generator* covers from 100kHz–50MHz and 70–120MHz, and is usable up to 150MHz. It generates CW (unmodulated), AM and FM signals suitable for a wide range of tests.

Steering Wheel Audio Button-to-infrared Adaptor

If you upgrade the radio or 'infotainment' head unit in a car with push-button steering wheel controls, those controls may stop working. This adaptor lets you use most of those very handy controls with a wide range of aftermarket head units.

Ultra-low-distortion Preamplifier with Tone Controls – Part 3

This high-performance *Audio Selector* can expand the number of inputs to the *Ultra-low-distortion Preamplifier*. It can also be used to 'upgrade' just about any piece of audio equipment with stereo line-level inputs or simply operate as a stand-alone device.

Make it with Micromite

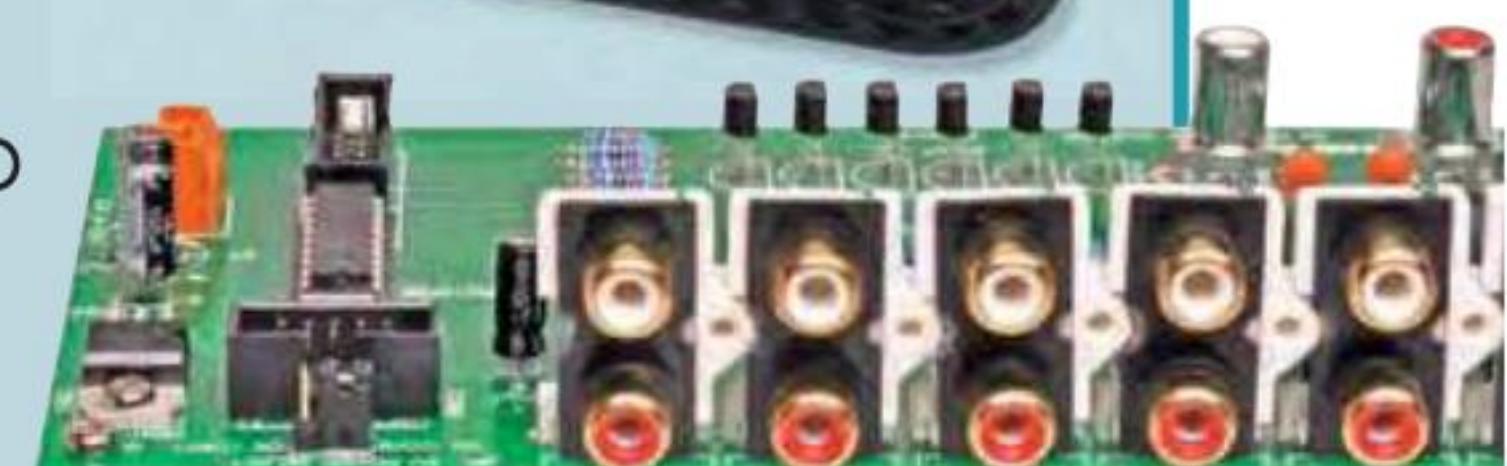
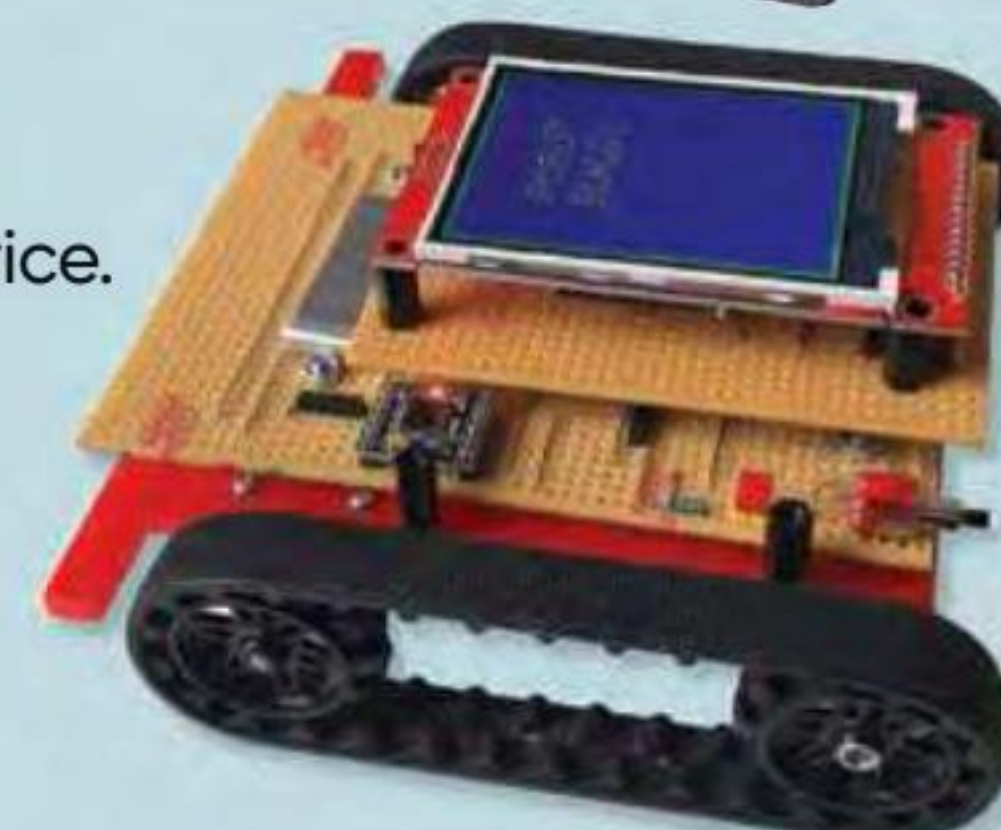
Next month, we continue our exciting programmable robot buggy project with assembly instructions and a detailed look at the Micromite-based electronics, including Bluetooth communication and a colour display.

Visual programming with XOD

In the June issue, we'll show you how to build a sophisticated ultrasonic distance sensing system that combines an Arduino with an ultrasound sensor and a 'clock' LED display. It's clever – uses an advanced Kalman digital filter – but easy to set up.

PLUS!

All your favourite regular columns from *Audio Out*, *Cool Beans* and *Circuit Surgery*, to *Electronic Building Blocks*, *Practically Speaking* and *Net Work*.



On sale 7 May 2020

Content may be subject to change

WELCOME TO JPG ELECTRONICS

Selling Electronics in Chesterfield for 29 Years

**Open Monday to Friday 9am to 5:30pm
And Saturday 9:30am to 5pm**

- Aerials, Satellite Dishes & LCD Brackets
- Audio Adaptors, Connectors & Leads
- BT, Broadband, Network & USB Leads
- Computer Memory, Hard Drives & Parts
- DJ Equipment, Lighting & Supplies
- Extensive Electronic Components
- ICs, Project Boxes, Relays & Resistors
- Raspberry Pi & Arduino Products
- Replacement Laptop Power Supplies
- Batteries, Fuses, Glue, Tools & Lots more...



T: 01246 211 202

E: sales@jpgelectronics.com

**JPG Electronics, Shaw's Row,
Old Road, Chesterfield, S40 2RB**

W: www.jpgelectronics.com



Retail & Trade Welcome • Free Parking • Google St View Tour: S40 2RB

NEW subscriptions hotline!

Practical Electronics

We have changed the way we sell and renew subscriptions. We now use 'Select Publisher Services' for all print subscriptions – to start a new subscription or renew an existing one you have three choices:

1. Call our NEW print subscription hotline:
01202 087631, or email: pesubs@selecttps.com
2. Visit our shop at: www.electronpublishing.com
3. Send a cheque (payable to: 'Practical Electronics') with your details to:
Practical Electronics Subscriptions, PO Box 6337,
Bournemouth BH1 9EH, United Kingdom

Remember, we print the date of the last issue of your current subscription in a box on the address sheet that comes with your copy.

Digital subscribers, please call 01202 880299 or visit: www.electronpublishing.com

Published on approximately the first Thursday of each month by Electron Publishing Limited, 1 Buckingham Road, Brighton, East Sussex BN1 3RA. Printed in England by Acorn Web Offset Ltd., Normanton WF6 1TW. Distributed by Seymour, 86 Newman St., London W1T 3EX. Subscriptions UK: £26.99 (6 months); £49.85 (12 months); £94.99 (2 years). EUROPE: airmail service, £30.99 (6 months); £57.99 (12 months); £109.99 (2 years). REST OF THE WORLD: airmail service, £37.99 (6 months); £70.99 (12 months); £135.99 (2 years). Payments payable to 'Practical Electronics', Practical Electronics Subscriptions, PO Box 6337, Bournemouth BH1 9EH, United Kingdom. Email: pesubs@selecttps.com. PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.

Faster Programming, Wider Voltage Ranges and Enhanced Interface Options

PICkit™ 4 enables faster design development



With five times faster programming and a wider 1.2V to 5V range, the Microchip MPLAB® PICKit™ 4 Development Tool supports low-cost development of even more Microchip controllers.

PICKit™ 4 also introduces improved USB connectivity with a hi-speed USB 2.0 interface and advanced debugging over 4-wire JTAG and serial wire debug with streaming data gateway in addition to legacy interfaces.

The new advanced interfaces support in-circuit programming and debugging of Microchip's CEC1702 hardware cryptography-enabled MCUs, in addition to dsPIC® Digital Signal Controllers and PIC® microcontrollers from 8- to 32-bit.



www.microchip.com/PICKit4eu

DCA75

Advanced Semiconductor Analyser and Curve Tracer



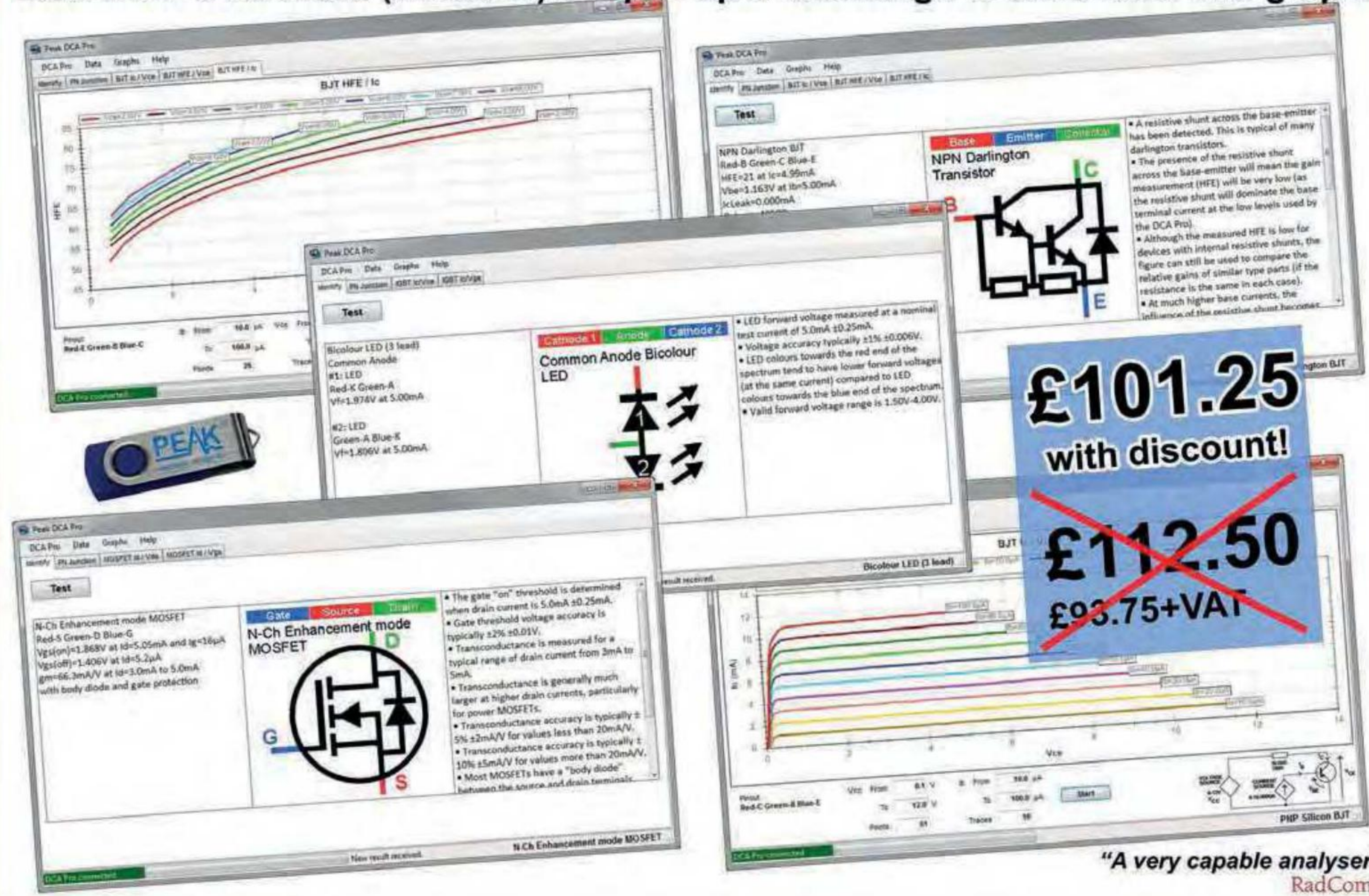
A versatile instrument that you'll love using for testing a huge range of semiconductor components.

Supports MOSFETs, transistors, diodes, LEDs, JFETs, IGBTs and more.

Connect any way round and let the **DCA Pro** identify the component type, pinout and lots of parameters.

Can be used standalone or connected to a Windows[®] PC (XP up to Win10).

Load the PC software (included) to open up a vast range of extra tests and graphs.



"A very capable analyser"
RadCom

It's only possible to show summary specifications here. Please ask if you'd like detailed data. Further information is also available on our website. Product price refunded if you're not happy.

Tel. 01298 70012
www.peakelec.co.uk
sales@peakelec.co.uk

Atlas House, 2 Kiln Lane
Harpur Hill Business Park
Buxton, Derbyshire
SK17 9JL, UK

